Safety Science 156 (2022) 105897

Contents lists available at ScienceDirect

Safety Science

journal homepage: www.elsevier.com/locate/safety

Bibliometric and scientometric analysis-based review of construction safety and health research in developing countries from 1990 to 2021

Nnedinma Umeokafor [a,*], Tariq Umar [b], Konstantinos Evangelinos [c]

[a] School of Civil Engineering and Built Environment, Liverpool John Moores University, Liverpool, United Kingdom
[b] Faculty of Environment and Technology, University of the West England, Bristol, United Kingdom
[c] Department of Environment, University of the Aegean, Lesvos 81100, Greece

ARTICLE INFO

Keywords:
Bibliometric analysis
Developing countries
Construction safety
Research trend
Systematic review
Scientometric analysis

ABSTRACT

This bibliometric and scientometric analyses and critical review of construction health and safety (H&S) research in developing countries (DCs) over the past 31 years, identifies its trends, dissemination, knowledge gaps, study implications, and direction of future research. These are area overlooked. Using a science mapping approach, involving systematic bibliometric analysis of the Scopus database and scientometric analysis with VOSViewer software, this research fills the knowledge gap. The findings include that while construction H&S research is growing in a few countries such as China and South Africa, the majority of DCs such as Venezuela are yet to experience this increase. However, the research focus is not aligned with their problems. The studies examined mainly focus on risk-based research (e.g. risk management and assessment), accidents, human-related factors, safety management, site safety, and performance management. The research focus of construction H&S scholars in DCs differs from their global counterparts. Equality, diversity and inclusion in construction H&S; and safety culture and climate are still minimal. Many aspects of industry 4.0 concerning safety need to be examined, for example, 'Big data and construction H&S', and industry 4.0 skills and knowledge requirements for construction H&S -associated activities. There is linear relationship (correlation) between keywords occurrences and their total strength. Mainly quantitative surveys and analytic hierarchy processes (AHP) are adopted, hence the need for qualitative methods studies. The study provides the first detailed evidence of the characteristics of construction H&S research in DCs and its underrepresentation in H&S research.

1. Introduction

Occupational health and safety is a legal and moral obligation with economic implications. Hence, it is one of the key performance indicators in projects (Musonda and Smallwood, 2008; Hare and Cameron 2012) and businesses, a pertinent ingredient for achieving sustainable development goals such as 3 (health and wellbeing) (Tunji-Olayeni et al. 2019). Consequently, it is becoming at the forefront of the corporate agenda (Umeokafor, 2017), and the COVID-19 pandemic been exacerbated this.

However, the occupational health and safety record of the construction industry remains poor (International Labour Organisation (ILO), 2017, 2018; Umeokafor et al. 2021) especially the developing countries (DCs) (Okonkwo 2019; Umeokafor et al. 2021). Despite the dearth of occupational safety and health research in DCs (Umeokafor 2018) and the potential of scientometric and Bibliometrics articles to address the limitations of traditional reviews (Zhao 2017), increase the confidence in review articles (Belter 2015) and offer in-depth and sophisticated analysis and visualised insight on the research trend and future direction of the subject (Jin et al. 2019a), there is yet to be one of such on occupational health and safety in DCs. Using the science mapping approach, this study examines the characteristics of construction safety and health research that focuses on DCs which are published in journals and conferences proceedings indexed in Scopus from 1990 to 2021. In doing this, the following objectives are set to guide the study:

- To identify the main research topics and focus of construction H&S research in DCs
- To identify gaps in knowledge in construction H&S research in DCs.
- To identify future direction for construction H&S research in DCs.
- To demonstrate the implications of construction health & safety research findings in DCs.

* Corresponding author.
E-mail address: nnedinmaik@hotmail.com (N. Umeokafor).

https://doi.org/10.1016/j.ssci.2022.105897
Received 3 October 2021; Received in revised form 4 July 2022; Accepted 6 August 2022
Available online 18 August 2022

To the knowledge of the author, this is the first detailed study of this nature that focuses on DCs. It follows on from Jin et al (2019a) which aims to introduce the science mapping approach into the domain of construction safety. Following this section is the literature review and rationale where a case for the current study is established, followed by the methodology which defines DCs, lists those examined in the study, and the overall research approach. In particular, the International Monetary Fund's definition of developing countries made of a list of 152 countries (see Worlddata, 2020) is used in the study. Of these countries, only 43 have publications indexed in Scopus in construction health and safety hence used. After the methodology, there is the presentation of the results and their discussions after which the implications of the study follow. The last section is where the conclusions, limitations and recommendations are covered.

2. Literature review and rationale

The construction industry globally has underperformed in occupational health and safety. There is evidence in Health and Safety Executive (2021) and ILO (2017, 2018) that the industry has an accident record that is disproportionate to its workforce and other industries. Studies such as Hämäläinen et al. (2017), Okonkwo (2019) and Umeokafor et al. (2021) also demonstrate that the cases of developing countries (DCs) are worse. For example, there is an under-reporting of accidents compared to developed countries (De Silva et al., 2018; Umeokafor, 2017), the fatality they report is three times more than their counterparts in developed countries (Okonkwo 2019). Their regulatory systems are complex and dysfunctional (Umeokafor et al. 2020), the occupational health and safety regulations are poor, outdated and the compliance with them low (Idoro 2008, 2011; Eyiah et al. 2019; Okonkwo 2019). The occupational accident fatality rate in low and middle-income African countries is 21.1 fatalities per 100,000 workers (Hämäläinen et al. 2017).

Consequently, in contributing to improving construction H&S through the advancement of knowledge in the subject, numerous studies have focussed on various areas therein. For example, studies in design for safety (DFS) include Umeokafor et al (2021), Manu et al. (2018, 2019); Regulation and compliance, Eyiah et al. (2019), Umeokafor et al. (2019); digital technologies and construction safety can be found in Guo et al. (2017) and Hou et al (2021), and decision-making and risk assessment in construction H&S are not limited to Ranjan et al. (2019) and Mete et al. (2019). Accidents in the construction industry are also in studies (Abdullah and Wern 2011; Yang et al 2020; De Silva et al., 2018).

While these studies have significant contributions to construction H&S research, there is still the need for review papers in in the subject (Jin et al 2019a). Kunisch et al (2018) demonstrate that review articles can show the characteristics of research in subjects and highlight areas of dominant research focus, gaps in knowledge and trends in the subject. This explains why there are several review articles on construction health, safety and well-being but not without limitations. Extant reviews on construction health, safety and wellbeing include Poghosyan et al. (2018) where DFS is the focus, Umeokafor (2018) who examines construction H&S trends in Nigeria, Chan et al. (2020) who focus on mental health risk factors in construction, and Nwaogu et al. (2020) where they use the science mapping approach to unearth the trend on mental health research in the construction industry. Further, Guo et al. (2017) sought to understand the trend in digital technologies in construction safety research, and Hou et al (2021) review literature on digital twins in construction worker safety. Suárez Sánchez et al. (2017), Jin et al. (2019a) and Luo et al. (2022) take a broader approach to advance the understanding of the construction safety research trend globally.

However, while these studies have done well in advancing the knowledge in construction H&S and wellbeing, they have limitations. For example, Chan et al. (2020), Poghosyan et al. (2018), Umeokafor (2018), Suárez Sánchez et al. (2017) and Guo et al. (2017) are at risk of bias (subjectivity) in review because they have adopted the traditional systematic approach to review where the scientometric and Bibliometric methodological approaches with a software are not used (Jin et al. 2019b; Zhao 2017; c.f Karakus et al. 2019; Belter 2015). The bias can be addressed by the scientometric approach (Jin et al. 2019a) and Bibliometrics (Belter 2015; Karakus et al. 2019). These can enable more in-depth and sophisticated analysis and discussion of literature (Jin et al. 2019a; Karakus et al. 2019) and bibliographic maps created, visualised, and explored with advanced technological support tools and techniques (Karakus et al. 2019). According to Pritchard (1969), bibliometrics is "the application of mathematical and statistical methods to books and other media of communication". With this, in addition to the above, bibliometric networks can be analysed, bibliographics coupled and their strengths shown (Karakus et al. 2019). Bibliometric indicators such as citations provide votes of confidence or influence among papers, indicating that the cited paper influences or has an impact on the one that cites it (Belter 2015). This explains why it is an indicator of the impact that papers, authors, countries, and journals have on science generally (Belter 2015). Also, bibliometric analysis ensures transparency in literature review and can examine a high number of publications than the traditional peer-review (Belter 2015).

Conversely, bibliometrics has limitations (Belter 2015; Choudhri et al 2015; Open University 2021). For example, in citation analysis, self-citation also counts, and other citations irrespective of the rationale and motivation (e.g personal relationship or even citation for negative reasons), are also not considered as impact (Belter 2015; Choudhri et al 2015; Open University 2021). Details of these limitations and more are covered in detail in the discussions section of this paper.

Further limitations of the existing reviews of construction H&S research include that although Jin et al. (2019a) and Luo et al. (2022) adopt a scientometric approach and bibliometrics in examining the subject, issues relating to DCs are unemphasised because they focus on its global trend. Also, Jin et al. (2019a) are limited to construction safety, overlooking health. Given the differences between developed and developing countries in terms of contexts, construction H&S performance, methods of construction and level of development, specific emphasis on H&S in construction in DCs is needed. The current review contributes to bridging this gap between developing and developed countries in meeting sustainable development goals. Further, Jin et al. (2019a) have excluded conference papers and Luo et al. (2022) omit to mention if they are covered in their paper or not. Given the imperativeness of this to academics in developing countries, as demonstrated elsewhere in this paper, this limitation is addressed. Further, Luo et al. (2022) have focused on only the Web of Science database despite the debatable downside, a matter handled in this paper. Based on the background established so far, this study addresses these limitations using the science mapping approach.

3. Methodology

This research is a literature review using the science mapping four-stage approach. This involved a bibliometric analysis of construction H&S research in DCs on the Scopus database and scientometric analyses of the data with VOSViewer software. Following this, the data was discussed and further inferential statistics, Pearson correlation analysis, was performed on Statistical Package for Social Science (SPSS). The fourth stage is the qualitative discussion. The overall process of the research is summarised in Fig. 1.

3.1. Bibliometric analysis

Using the evaluative and descriptive approaches, the bibliometric analysis adopts a hybrid technique to present or capture research trends and features of publications, according to McBurney and Novak (2002). This first stage of the research method commenced with a bibliometric search of the Scopus database on 20 July 2021 covering the years, 1990 to 2021. Studies such as Jin et al. (2019a) and Umeokafor 2018 have

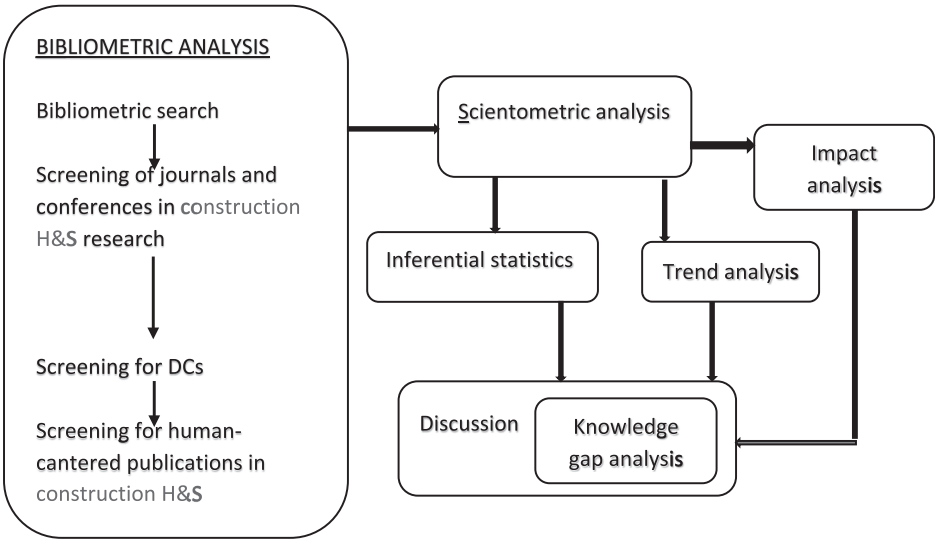


Fig. 1. Summary of the overall research methodology.

used or included Scopus as one of the databases for their research. Aghaei Chadegani et al. (2013) and Vieira and Gomes (2009) found that Scopus contains more recent and broader range of journals than Web of Science. This is up to 20 per cent more coverage than Web of Science. The search focused on title, abstract and keywords. The search words with the range of years covered are: (TITLE-ABS-KEY ('construction AND health AND safety') OR TITLE-ABS-KEY ('occupational AND health AND safety') AND TITLE-ABS-KEY ('developing AND countries' OR 'emerging AND economies') OR TITLE-ABS-KEY ('construction AND safety') OR TITLE-ABS-KEY ('safety AND in construction')) AND PUBYEAR > 1989 AND PUBYEAR < 2022. This resulted in 8,087 documents. Then the search was limited to the following subject areas: 'Engineering', 'Social science', 'Environmental Science', 'Business, Management and Accounting', 'Energy', which resulted in 5,378 documents. While other reviews such Jin et al. (2019a) has only considered articles, Adjei and Owusu-Ansah (2016) and Umeokafor (2018) found that many academics in DCs mainly publish in peer-reviewed national and international conference proceedings.

Consequently, the research was further refined and limited to documents (articles, and conference papers). This resulted in 4,722 documents. Examining journal and conference publications and book chapters in bibliometric and scientometric analyses is consistent with studies such as Fabregat-Aibar et al. (2019). Using the International Monetary Fund definition of developing countries made of 152 countries, the appropriate countries were selected from Worlddata (2020). Fourty-three countries that met this definition and have publications on Scopus in the subject were selected. The countries are China, Turkey, South Africa, Saudi Arabia, Malaysia, Nigeria, India, Jordan, Kuwait, Iran, Brazil, Egypt, Indonesia, Vietnam, Thailand, Oman, Romania, Serbia, Bangladesh, Zimbabwe, Ghana, Sri Lanka, Trinidad and Tobago, Kazakhstan, Morocco, Pakistan, Philippines, Lebanon, Ukraine, Brunei, Colombia, Mexico, Yemen, Argentina, Chile, Ecuador, Iraq, Kenya, Peru, Qatar, Uzbekistan, Venezuela. Then, 1,613 documents were found. It was further limited to journals and conferences, then 1517 documents were found. All on the dashboard were reviewed and some that were supposed to be excluded were still found, for example, publications in medical journals, in the UK, USA, Australia, Germany, Spain and France. After these were excluded, the result was 589 documents. This was then used in the scientometric analysis.

3.2. Scientometric analysis

The second stage of the research was the Scientometric analysis where VOSViewer software was adopted. Here the data from the bibliometric analysis was imported and used. While CitNetExplorer and VOSviewer are among the most popular software design for retrieving, visualising and analysing publication information (Van Eck & Waltman, 2014; Van Eck et al. 2017), VOSviewer software was used for its convenience to the authors. Using text mining, the software constructs and visualises the occurrence network of relevant terms in publications; it enables the visualisation of bibliometric networks (VOSViewer.com, 2021), document analysis (covering citations, authorship, co-authorship, country, and organisation), keywords analysis, and journal sources. A threshold (ranging from 1 to 10) was set for each of the analyses, and these are detailed against each of them in the results and discussions sections.

3.3. Inferential statistics

Pearson correlation analysis of the journal indicators, total link of strength, total citations, number of publications and average citations was conducted on SPSS.

3.4. Discussion

The major keywords in the clusters are discussed in detail here. Drawing on this and other analysis including data obtained from the bibliometric analysis of 589 papers imported into VOSViewer, the research trends, knowledge gaps and future directions of construction health and safety in developing countries research were unearthed.

4. Results

Fig. 2 is a graphical presentation of the research trend from 1994 to 2022 in DCs. It shows that no research before 1994 in construction H&S in journals and conferences proceedings meets the criteria set. Also, the figure shows that construction H&S research in the countries has fluctuated from 1994 till 2018 where it has increased rapidly. There is also evidence therein that from 1994 till 2008, there was always less than 20 publications and between 21 to just over 40 publications from 2010 till 2016. To date, there has not been over 100 construction H&S research publications in any year. Comparing this to Jin et al. (2019a) where construction safety research globally in selected journals were examined, it can be argued that if Journals were only considered in the current study, the findings in Fig. 2 would likely be reduced in number.

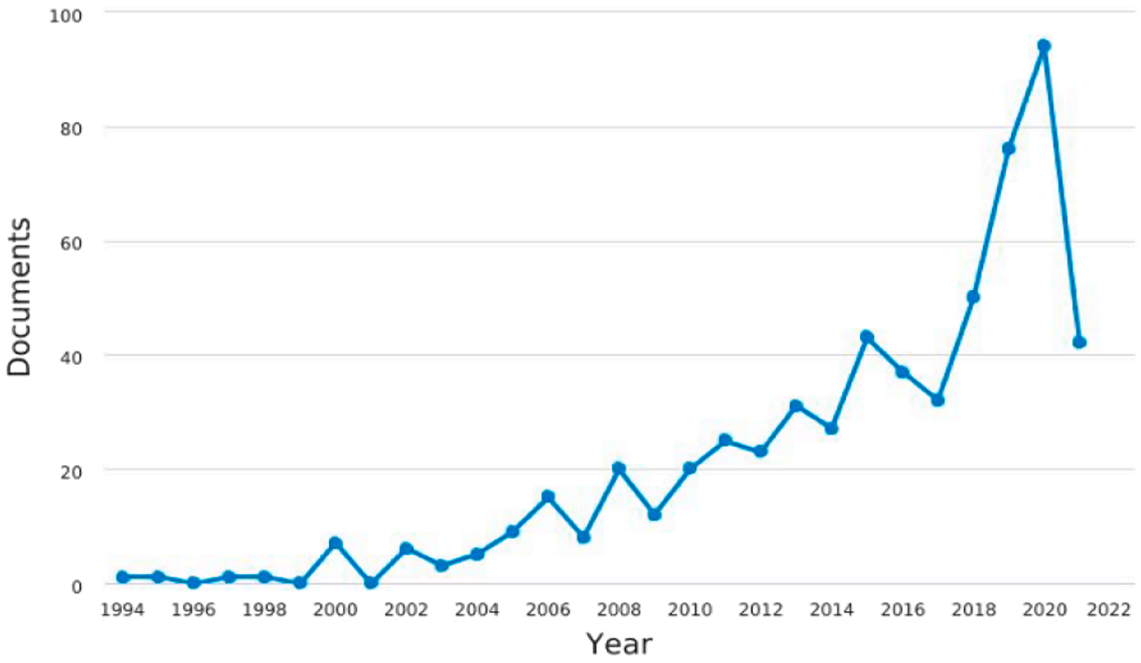
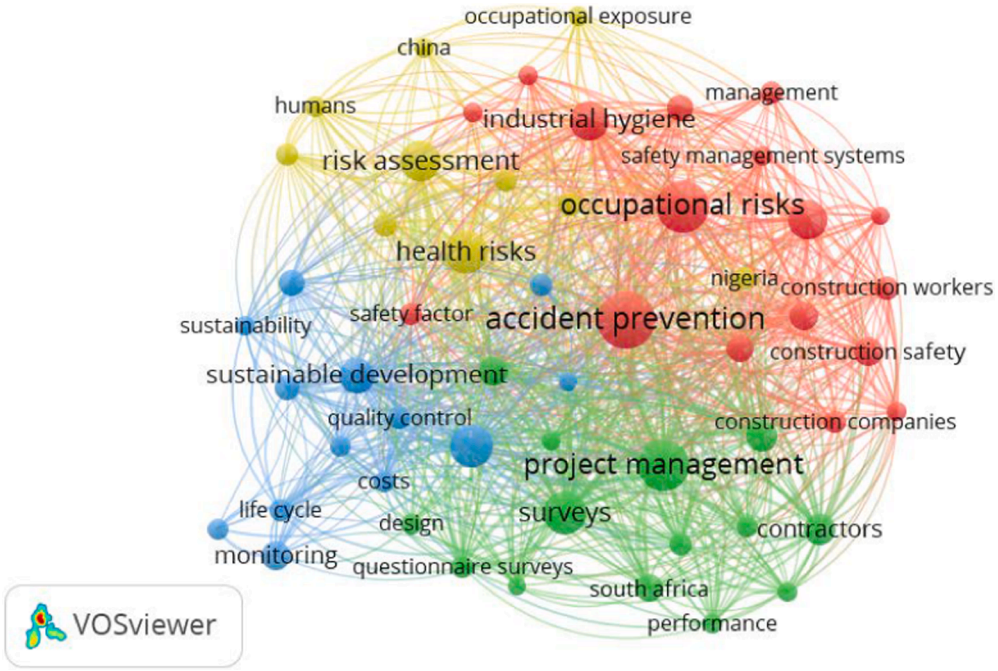


Fig. 2. Analysis by articles in the construction H&S in DCs journals and conferences proceedings from 1994 to 2022.

4.1. Keywords analysis

4.1.1. All keywords analysis

Babaii and Taase (2013) demonstrate the roles of keywords in articles including that they depict the essence of the topic examined in the documents. By implications, analysing them shows the areas of focus of extant research and can provide auxiliary support for research. For example, the co-occurrence of keywords unearths the link, or as Jin et al (2019a) put it, the inter-closeness among them. In the current study, author and index keywords are analysed and presented in Fig. 3 where the four clusters are also found. These clusters are detailed in Figs. 4, 5, 6 and 7 based on highest occurring keyword. In running the co-occurrence analysis of all keywords (author and indexed), the full counting option on the VOSviewer was used, and the minimum number of occurrences of a keyword set was 10. From the 4000 keywords, 68 keywords met the threshold and were used in the analysis. Following this, in line with Jin et al. (2019a), common keywords such as 'construction industry', 'occupational risks', 'occupational health and safety', 'literature



Key: Cluster 1 — red; Cluster 2 — green; Cluster 3 — Blue; Cluster 4 — gold or yellow. The biggest blue node with missing name is safety engineering

Fig. 3. Visualisation of all keywords (author and indexed).

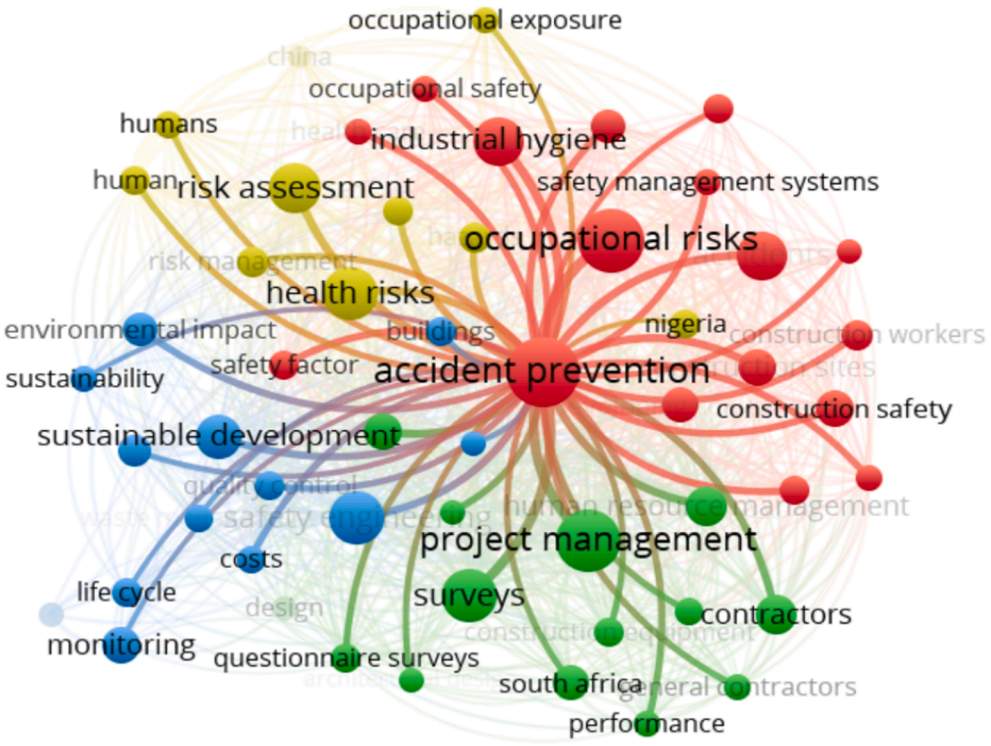


Fig. 4. Keywords in Cluster 1 (in red) based on highest occurring keyword. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

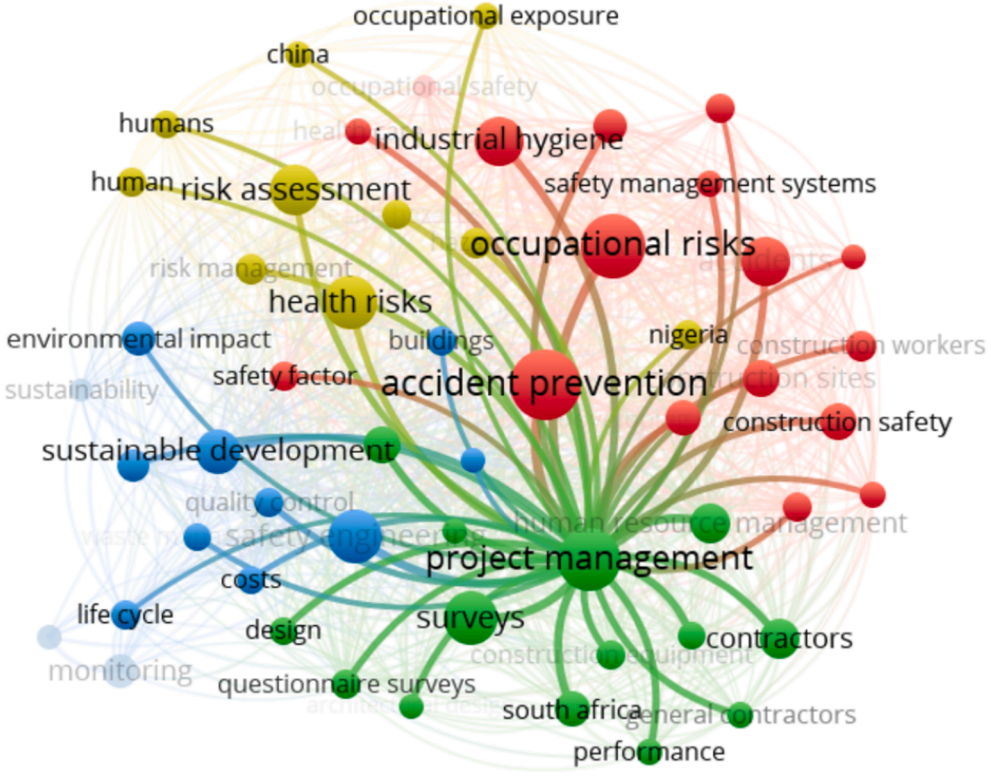


Fig. 5. Keywords in Cluster 2 (in green) based on highest occurring keyword. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

reviews', 'construction sites', 'design/methodology/approach, 'research', 'construction management', 'safety and health' were excluded. Also, keywords like 'civil engineering', 'bridges', 'concrete', 'structural safety', 'concrete construction', 'structural health monitoring' 'reinforced concrete' were removed because they relate to structural safety (which is the broad health and safety', not occupational

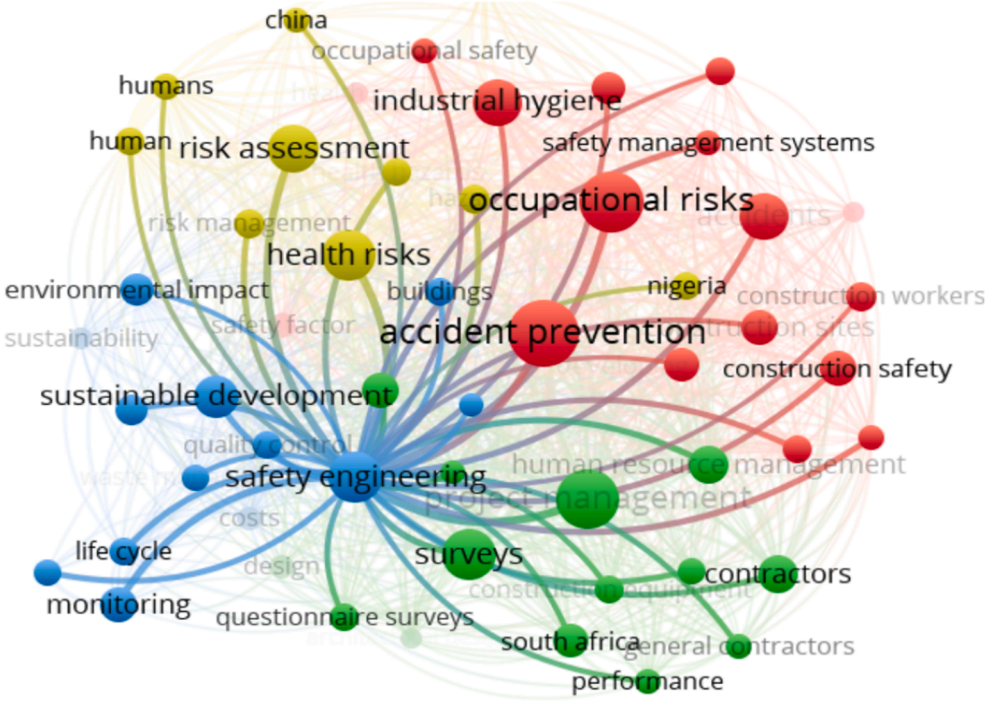


Fig. 6. Keywords in cluster 3 (in blue) based on highest occurring keyword. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

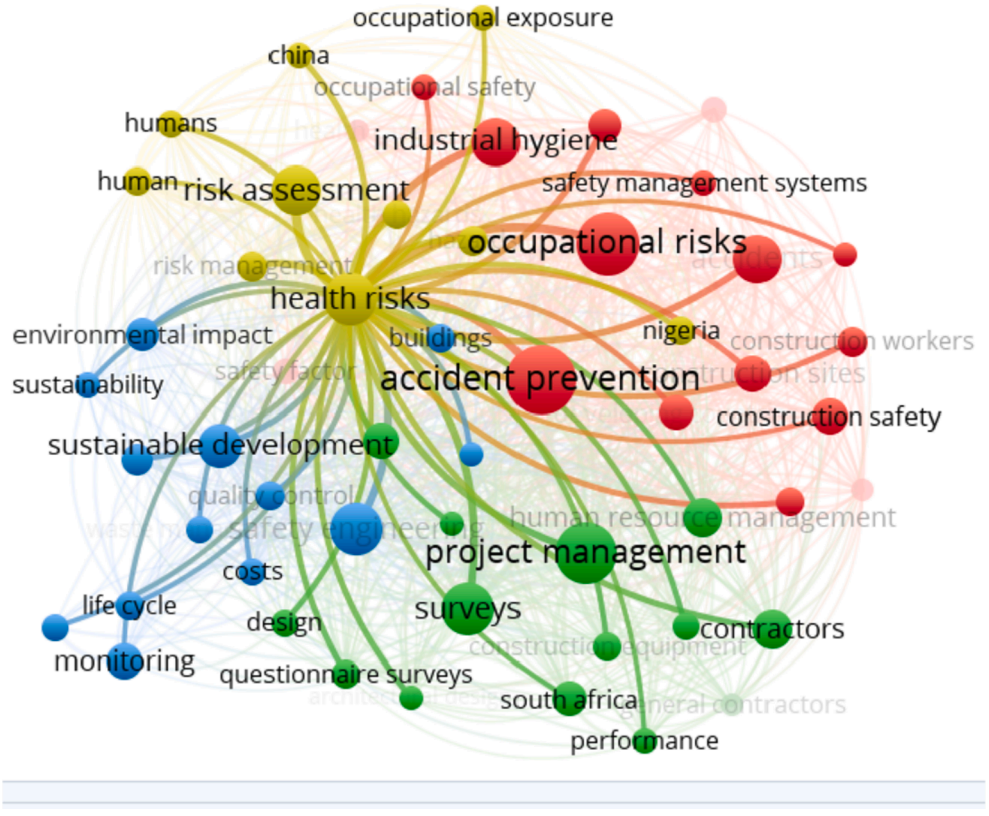


Fig. 7. Keywords Cluster 4 (in yellow) based on highest occurring keyword. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

health and safety. The clusters show that the keywords are co-studied together (Jin et al. 2019a).

While the clusters are detailed individually below, Fig. 3 shows the interconnectedness of all the clusters and keywords. The bigger the nodes (circles) the larger the weighting. The shorter the distance, the stronger the strength. The closer the location of a cluster, the more

related they are in terms of citations but the further they are, the less closely related they are to each other (Van Eck et al. 2017). The curved lines show the relatedness (ibid). Fig. 3 shows that occupational exposure closely relates to management and humans and occupational risks. It also shows that cost is very closely related to design, quality control and project management more than it is to accident prevention. This is, for example, where Akawi and Musonda (2021) establish a pricing framework for H&S in construction projects showing how contractors and clients adequately evaluate bids or the variations in projects towards health and safety compliance and accident prevention. Also, in Fig. 3 accident prevention closely relates to project management, and the latter has a closer link with performance and contractors. This includes studies that focus on advancing the understanding of how feedback mechanisms and how the pressure from productions impacts safety performance (Mohammadi and Tavakolan 2019). Sustainable development and link with health risk and occupational hazards in Fig. 3 are evident in studies such as Tunji-Olayeni et al. (2019).

Quantitative analysis in Table 1 shows the occurrence of the keywords — number of documents the keywords occur in, average citations average publication year and average normalised citations. According to Van Eck, and Waltman (2021: 37), the normalised number of citations of a document is equal to the number of citations of the 'document divided by the average number of citations of all documents published in the same year and included in the data that is provided to VOSViewer. The normalization corrects for the fact that older documents have had more time to receive citations than more recent documents'. Then the 'average normalised citation is the average normalised number of citations received by the documents in which a keyword or term occurs or the average normalised number of citations received by the document published by sources, an author, organization, or a country'. (Van Eck, and Waltman, 2021: 37). The table shows that while the keyword with the highest occurrence in publications is 'accident prevention', 'humans' has the highest average citation. The table indicates that studies with higher average normalised citations are likely to have a higher impact research community in construction safety research (Jin et al 2019a). For example, studies that focus on 'human factors' (Moshood et al 2020) and safety management (Idoro 2008) are likely to higher impact on construction H&S research in DCs. This may not always be the case as Moshood et al (2020) is yet to create the level of impact based on citations. The research methods adopted for research suggest the level of impact it can have in the construction H&S research community. Adopting questionnaire surveys for H&S in construction in DCs is likely to result in a higher impact on the research community (Table 1).

Pearson's correlation coefficient analysis of all keywords was conducted on measurement indicators in pairs to see if there are correlations (linear relationships) among them. The following were found thus: keywords occurrences and their total strength are strongly positively correlated ($r = 0.963$, n = 54, $p = .000$), significant at the 0.01 level; occurrences and average citations show no correlation, just as between occurrences and average normalised citations, and total link and average citations. However, normalised citations and average citations are strongly positively correlated ($r = 0.803$, n = 54, $p = .000$) significant at the 0.01 level.

Fig. 4 focuses on one of the clusters in Fig. 3, cluster 1. It shows that occupational risks are co-studied with accident prevention. The distance between accident prevention and occupational safety is longer showing that both are less co-studied. Fig. 3 suggests gaps in knowledge which are detailed later in this paper. For example, the distance between management and accident prevention indicates limited research that considers the role of management in accident prevention. 'Construction workers' and 'Construction safety' in construction companies tends to be co-studied together (Figs. 2 and 3). Cluster 3 shows a close connectedness between safety engineering and quality control but cost, sustainable construction, suitability and quality control are also co-studied (Figs. 3 and 6).

Table 1
Quantitative of summary of impact of all keywords (author and indexed) in construction H&S research in DCs.

Keyword	Occurrences	Average publication year	Average citations	Average normalised citations
Humans	13	2015	21.69	2.58
Safety Management	10	2016	21.60	2.33
Nigeria	14	2017	12.00	2.09
Questionnaire Surveys	14	2015	6.21	1.98
Decision Making	17	2016	14.94	1.93
Contractors	26	2013	11.04	1.87
Construction Projects	23	2016	11.43	1.77
Buildings	14	2013	13.79	1.76
Safety Performance	11	2015	10.91	1.74
Industrial Hygiene	40	2015	8.53	1.74
Sustainability	12	2016	9.33	1.63
Hazards	16	2014	21.50	1.60
Health Hazards	14	2015	2.38	1.55
Risk Assessment	42	2014	12.45	1.52
Surveys	49	2014	9.47	1.42
Risk Management	16	2012	7.75	1.42
China	11	2014	1.42	1.42
Sustainable Development	34	2015	7.50	1.40
Quality Control	15	2012	6.80	1.38
General Contractors	11	2011	5.73	1.37
Construction Sites	24	2015	4.12	1.33
Waste Management	13	2013	7.75	1.30
Occupational Risks	69	2014	5.46	1.30
Health Care	12	2005	9.58	1.26
Construction Equipment	14	2014	6.29	1.20
Occupational Exposure	11	2015	3.36	1.20
Accident Prevention	81	2012	6.12	1.18
Health Risks	49	2014	5.10	1.11
Construction Safety	23	2016	3.17	1.11
Costs	13	2013	4.92	1.10
Safety Factor	15	2010	15.47	1.04
Monitoring	24	2015	4.92	1.01
Construction Accidents	10	2013	4.00	1.01
Construction Workers	16	2016	2.69	0.99
South Africa	21	2010	5.43	0.98
Occupational Safety	11	2013	3.73	0.95
Project Management	65	2012	5.45	0.94
Accidents	41	2013	4.05	0.94
Developing Countries	22	2014	4.91	0.91
Life Cycle	15	2015	3.73	0.85
Performance	12	2014	4.75	0.77
Safety Engineering	47	2014	3.17	0.76
Design	13	2011	3.62	0.75
Environmental Impact	19	2011	4.63	0.70
Management	14	2013	3.93	0.70
Architectural Design	10	2016	2.60	0.70
Laws and Legislation	19	2011	2.53	0.61
	13	2014	2.38	0.59

(continued on next page)

Table 1 (*continued*)

Keyword	Occurrences	Average publication year	Average citations	Average normalised citations
Health Monitoring				
Human Resource Management	26	2015	1.65	0.54
Construction Companies	14	2014	3.14	0.51
Construction Activities	10	2013	0.70	0.38
Construction Management	13	2014	1.69	0.37
Safety Management Systems	11	2010	1.27	0.25

'Average normalised citation is the average normalised number of citations received by the documents in which a keyword or term occurs or the average normalised number of citations received by the document published by sources, an author, organization, or a country' (van Eck, and Waltman 2021: 37).

4.1.2. Author keywords analysis

To gain a different understanding of the scope of research from the authors' perspective and the valuable information they offer in human and automatic indexing (Gil-Leiva and Alonso-Arroyo 2007; Babaii and Taase 2013), author keywords analysis was conducted and presented in Table 2 and Fig. 8. Further, comparing it to all keywords analysis will offer unique insight into the discourse.

When running the co-occurrence of author keywords only, four was set as the threshold — the minimum number of occurrences of the keyword. This is consistent with Jin et al. (2019a). Of all the 1288 keywords, 41 met the threshold but during further refinement, some common ones such as occupational safety, health and safety, construction industry, and construction were removed. Of the 28 keywords left, only 25 of them had the largest set of connections hence used. The three without a large set of connections are 'health monitoring' with the occurrence '7', 'Ergonomics' with the occurrence '5' and 'Buildings' with an occurrence of 4. The findings are presented in Table 2 and network visualisation in Fig. 8.

Table 2
Quantitative summary of author keywords impact in construction H&S research in DCs.

Keyword	Occurrences	Average publication year	Average citations	Average Normalised citations
Analytic Hierarchy Process (AHP)	5	2016	42.00	4.51
Risk Management	5	2013	5.40	2.38
Risk Assessment	13	2015	16.85	2.31
Covid-19	4	2021	1.25	2.19
Workers	4	2016	3.00	2.14
*Accidents	5	2016	5.80	2.08
*Construction Site	6	2019	2.17	1.96
Productivity	5	2016	8.40	1.87
Contractors	8	2012	11.75	1.69
Sustainability	7	2017	4.86	1.28
Sustainable Construction	4	2018	1.50	1.28
System Dynamics	4	2016	5.00	1.21
Hazards	4	2014	2.75	0.98
Building Information Modelling	4	2018	2.50	0.81
*Accident	7	2016	6.29	0.80
Performance	12	2014	4.75	0.77
South Africa	11	2013	2.73	0.77
Simulation	4	2012	5.00	0.76
Risk Analysis	5	2014	29.40	0.70
Risk	6	2016	3.17	0.65
Environment	4	2014	0.75	0.62
Management	7	2013	2.29	0.42
*Construction Sites	5	2017	2.00	0.37
Lean Construction	4	2015	1.00	0.31

*Combining accident and accidents, the occurrence will increase, for example from 7 to 13, construction site/sites occurrence will increase to 11. The same is likely applicable to citations.

The same principles applied in all keyword analysis is applicable here. For example, there are two clusters here. For example, accident, risk and contractors are closely related and co-studied. One example is the examination of the impact of accidents and hazards on the construction industry of Ghana (Osei-Asibey et al. 2021). Just like all keyword findings, research gaps are indicative here (Table 2 and Fig. 8). Studies such as Aminbakhsh et al. (2013) which use Analytic Hierarchy Process as methodology is likely to have a higher impact on construction H&S research in developing countries (Table 2). The strong link between environment and sustainability in Fig. 8 can be found in noise pollution and construction sustainability studies such as Ning et al. (2019).

4.1.3. Comparing all keyword analysis and author keyword analysis

Tables 1 and 2 and Figs. 3 and 8 share a lot in common, for example, the high occurrence of accident-related keywords, and the high likelihood of a research method and/or methodology (such as questionnarie survey and Analytic Hierarchy Process) having a higher impact in the research community. Risk assessment also highly occurred in both analyses. However, author keywords show a strong link between covid-19 and workers, suggesting its examination in DCs in terms of health and safety. For example, Simpeh and Amoah (2021) assessed the measures in place to reduce Covid-19 on construction sites in South Africa. The likelihood of covid-19-related health and safety research in construction having a high impact is noted, given its average normalise citation of 2.19. The strong connection between systems thinking and stimulation is also evident in Fig. 8 and Table 2, unlike Fig. 2 and Table 1. Table 1 and Fig. 2 show a very high focus on human factor-related research construction H&S in DCs but the same level of emphasis is not in Fig. 8 and Table 2. The implication of this is that the use of both analyses offers unique insight into the subject, supporting the positions of Gil-Leiva and Alonso-Arroyo (2007) and Babaii and Taase (2013). The two analyses complement each other.

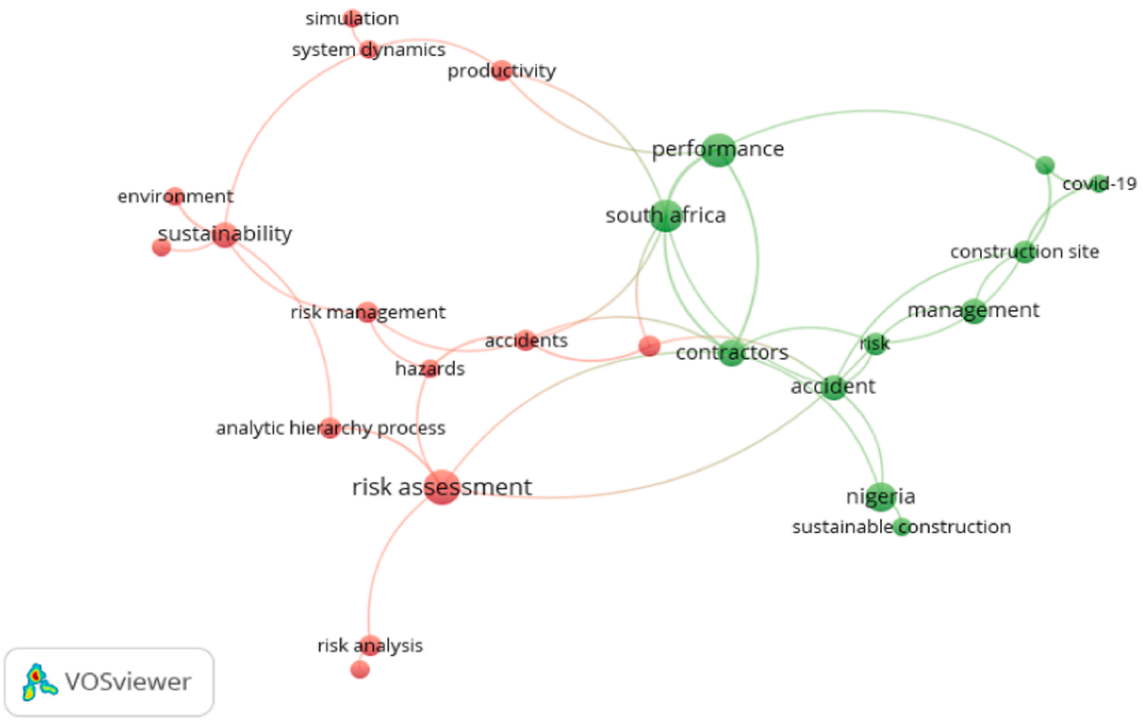
Just like all keywords, Pearson's correlation coefficient analysis was conducted on the measurement indicators in pairs to determine if there are correlations (linear relationship) among them. It shows that there is a linear relationship (correlation) between occurrences and total strength but in this case moderate positive ($r = 0.655$, n = 25, $p = .000$) significant at the 0.01 level. The other indicators, just as in all keywords, were not correlated except 'average normalised citations and average citations ($r = 0.610$, n = 25, $p = .001$) significant at the 0.01 level.

4.1.4. Main direction of construction H&S research in developing countries

Drawing on Tables 1 and 2 and Figs. 3–8, the main directions of construction H&S research in developing countries are presented. The details of the associated studies therein were obtained from the bibliometric analysis (of 589 papers) data imported into VOSViewer. Where possible, examples of associated papers are cited.

Safety management: Here (Figs. 3–7 and Table 1), studies focus on how it impacts the performance of the industry (Idoro 2008), measuring safety programmes (Aksorn and Hadikusumo 2008), safety culture (Williams et al. 2020) and Covid-19 (Simpeh & Amoah 2021). Other studies are H&S management practices (Aghimien et al., 2019); H&S management systems in construction contractor organisations (Okonkwo and Wuim 2020), and Safety management in infrastructure projects (Ammad et al. 2020).

Accident prevention and management: A lot of research (as



- The red one risk analysis is 'Building Information Modelling'.
- The green one above Covid-19 is 'Workers'.
- Cluster 5 — red; Cluster 6 — green.

Fig. 8. Visualisation of author keywords analysis only.

highlighted in Figs. 3, 4, 5, 6 and 7 and Table 1) focus on construction site safety such as how construction workers respond to thermal in summer (Fang et al., 2021), semiotics for H&S signs comprehension on construction sites (Alara et al 2019), scaffolding and H&S (Smallwood 2006), accident analysis of the industry (Abdullah and Wern 2011) and accident prevention (Yang et al 2020). Under-reporting of construction accidents (De Silva et al., 2018), assessing accidents on construction sites and the role of management are also covered. Accident prevention is interlinked to project management which is closely related to design (Figs. 3, 4 and 5). This is evident in studies such as Kasirossafar et al. (2012) where digital technology such as 3D/4D BIM tools for sustainable design.

Hazards including prevention through design, occupational and health risks: Industrial hygiene is closely interlinked with occupational safety and occupational exposure, explaining studies on dust diffusion modelling (e.g. Guo et al. 2020), noise population reduction in construction and sustainability (Ning et al. 2019), occupational hazards and safety issues on construction sites in India (Neeharika et al. 2018), occupational heat stress on labour productivity in construction in India (Chinnadurai et al., 2016); industry 4.0 and occupational health (Smallwood et al. 2020). Further, prevention through design is covered in the following: prevention of health hazards in buildings using smart technology (Oke et al. 2017), hazards prevention through sustainable design (Kasirossafar et al. 2012),attributes critical to designers for DFS in Malaysia (Ismail et al 2021), prevention through design education for civil engineers in Malaysia (Che Ibrahim et al. 2021), and design and construction ergonomics (Smallwood 2016).

Risk-related studies: An extensively researched area as seen in Tables 1 and 2 and Figs. 3 and 8. On further examination of the bibliometric analysis data on risk assessment studies, relevant studies include a novel approach for assessing construction health and safety and environmental risk assessment on construction projects (Yang et al 2020), H&S risk assessment matrix and decision making (Ranjan et al. 2019), and decision-support systems in risk assessment (Mete et al. 2019). Further studies that relate to risk cover, having an integrated risk management system (quality, health and safety and environment management) (Masuin et al. 2019), occupational health and safety risk in construction (Amin et al. 2019), and differences in construction stakeholder perception of occupational health and safety risks (Abas et al 2020).

Human factors in construction safety: Evidenced as highly ranked in Table 1 and inferred from Figs. 3 to 7, according to the bibliometric analysis data, this covers human factor influence in risk attitude in construction (Moshood et al 2020), the role of the project manager in H&S (Agyekum et al. 2020; Tayeh et al. 2020), human factor influence on contractor risk attitudes (Taofeeq et al., 2020), and the influence of designers on H&S (Smallwood 2004).

Performance and productivity: The link between performance and productivity (Fig. 8) is in studies that examine worker performance improvement through health and safety (Ayessaki and Smallwood, 2017), occupational heat stress on construction labour productivity (Chinnadurai et al., 2016), unsatisfactory working conditions and productivity (Abrey and Smallwood 2014),and organisational performance improvement through knowledge-based integration management systems, quality, safety and environmental (Apriyati and Latief 2020); all according to the bibliometric analysis data.

Sustainable development. Figs. 3–8 show this and bibliometric analysis data expands. For example, it has a link with health risks where there is a focus on how occupational risks impact the construction industry in countries (for example Nigeria) in meeting sustainable development goals such as 1 (no poverty), 3 (health and wellbeing) and8 (decent work (Tunji-Olayeni et al. 2019). There is also attention on sustainable design for safety in construction (Kasirossafar et al. 2012).

Sustainability and H&S: Figs. 3–8 show this and bibliometric analysis data expand with specific studies. For example, Cluster 3 (Fig. 6) shows the strong interrelationship between environmental impact and safety

engineering and sustainable development, and Figs. 3, 4, 5 and 7 demonstrate a less strong link between project management and life-cycle, health risk and accident prevention. Here, studies are not limited to cultural values influence on strategic and operational aspects of construction safety management in sustainable business management (see Sambandan et al. 2021), effect of client types on the relationship between green construction practices and H&S performance in Onubi et al. (2020), and risk factors for construction worker safety towards sustainability in Asad et al. (2020).

Analytic Hierarchy Process is dominant in H&S in construction research in DCs (Table 2), especially in risk assessment (Aminbakhsh et al. 2013; Janackovic et al., 2013; Masuin et al. 2019) and sustainability.

4.2. Journal and conferences source analysis

According to Tang et al (2018), journal co-citation analysis excels in advancing the understanding of the structure and feature of a subject (in this instance H&S) and characteristics of the journals (in the case of this study, papers in journal and conference proceedings). To run the citation of sources analysis resulting in the data in Table 3 and Fig. 9, 3 was set as the threshold for the minimum number of documents of a source on VOSViewer. Of the 282 sources, 39 meet the thresholds hence used for the analysis. Some of the 39 sources are not connected, only the 9 are connected but the 7 with strong connections are presented in Fig. 9. The connection between the Journal of Engineering, Project, and Production Management is low hence only visible when the scale is adjusted. Fig. 9 shows the mainstream journals and conferences in construction health and safety in DCs and Table 3 captures the total link strength, documents (the number of publications in each journal over 31 years), the citations, and average citations, average normalised citations, and average publications year of only six of the sources. Only 6 that have an 'average normalised citation of over 0.00 are presented in the table.

The size of the nodes in Fig. 9 shows the activity of the journal/conference and the number of publications (Tang et al 2018). The smaller the distance between two nodes, the higher the citation frequency (Tang et al. 2018). For example, Construction Management and Economics has 101 citations and the Journal of Engineering, Design and Technology has 51 (Table 3). In Fig. 9, the yellow node is a conference and the red and green ones are journals.

The impact of journals and conferences in the construction H&S scientific community is indicated by the average normalised citations. For example, publications in the 'Architectural Engineering and Design Management' and 'Construction Management and Economics' are likely to have a higher impact on the community than in the Journal of Engineering, Design and Technology, as seen in Table 3. The table also shows that a higher citation does not result in higher average normalised citations (see Architectural Engineering and Design Management vs Procedia Engineering in Table 3).

Pearson's correlation coefficient analysis on the measurement indicators (total link strength, average normalised citations, average citation, citations, and documents) in Table 3 have been conducted to determine if there are correlations (linear relationship) among them. Conducting the analysis in pairs, it was found that there is no correlation between them except for two, citations and documents with a strong positive correlation ($r = 0.762$, n = 8, $p = .028$) significant at the 0.01 level.

4.3. Document analysis

4.3.1. Co-authorship analysis

Co-authorship analysis is one of the document analyses conducted here. According to Fonseca et al (2016), the hallmark of contemporary academic research is scientific collaborative networks. They demonstrate that co-authorship analysis enables the visualisation of cooperation patterns between or among individuals and organisations. To run by country, a threshold of a minimum number of documents for a country was set as 2, and of the 43 countries, 28 met it. On running the analysis, of the 28, only 9 are connected and shown in Fig. 10. The association strength normalisation analysis is run here. Table 4 captures the total link strength of the countries in terms of co-authorship and the visualisation in Fig. 10 suggests that their geographical locations may determine the co-authorship. In particular, the closer authors are, the more likely they will co-author. For example, Nigeria, Ghana and South Africa are closely located geographically and in Fig. 10.

The same analysis was conducted but based on authors. The threshold, the minimum number of documents of an author, was set at 2. Of the 1310 authors, 150 met it. However, only 25 of them with the largest connections are presented in Fig. 11.

4.3.2. Citation analysis of authors

Citation impact assesses the usefulness, accuracy and importance of publications, sources or countries hence viewed as an alternative to showing research quality (Bornmann and Wohlrabe 2019; Martin and Irvine 1983). Despite the limitations of citation analysis, for example, that citation count does not really imply breakthrough research, experts of bibliometrics generally acknowledge it as a good but imperfect impact measurement indicator (Aksnes et al., 2019). By implication, the impacts of the author, document or journal are suggested by citation analysis.

In doing the above, the minimum number of document set as the threshold for each author was 3. Of the 1310 authors, 42 met the threshold hence were included in the analysis. However, only 11 have the largest set of connections and presented in Fig. 12. While Fig. 12 shows the relationship in citation among the main authors, Table 5 details it. The table shows the quantitative measurement of the major authors in construction H&S based on citations, indicating the impact that the authors have on the scientific community. It contains more details of the authors with the largest set of connections in terms of the 'average citations', 'average publication year', 'normalised citations', and 'average normalised citations. According to Van Eck et al. (2017), older documents are likely to have more citations than recent ones hence

Table 3
Quantitative summary of journal and conferences impact based on association strength citation analysis.

Source	Total Link Strength	Documents	Citations	Average citation	Average publication year	*Average normalized citations
Architectural Engineering and Design Management	2	3	21	7	2017	3.43
Construction Management and Economics	2	5	101	20.20	2011	2.91
International Journal of Construction Management	3	6	15	2.50	2020	2.76
Engineering, Construction and Architectural Management	1	4	16	4	2018	1.56
Procedia Engineering	4	18	149	8.28	2014	1.43
Journal of Engineering, Design and Technology	6	13	51	3.92	2017	0.91

*'Average normalised citation is the average normalised number of citations received by the documents in which a keyword or term occurs or the average normalised number of citations received by the document published by sources, an author, organization, or a country' (van Eck, and Waltman 2021: 37). Only 6 has an 'average normalised citation of over 0.00 hence presented in this table.

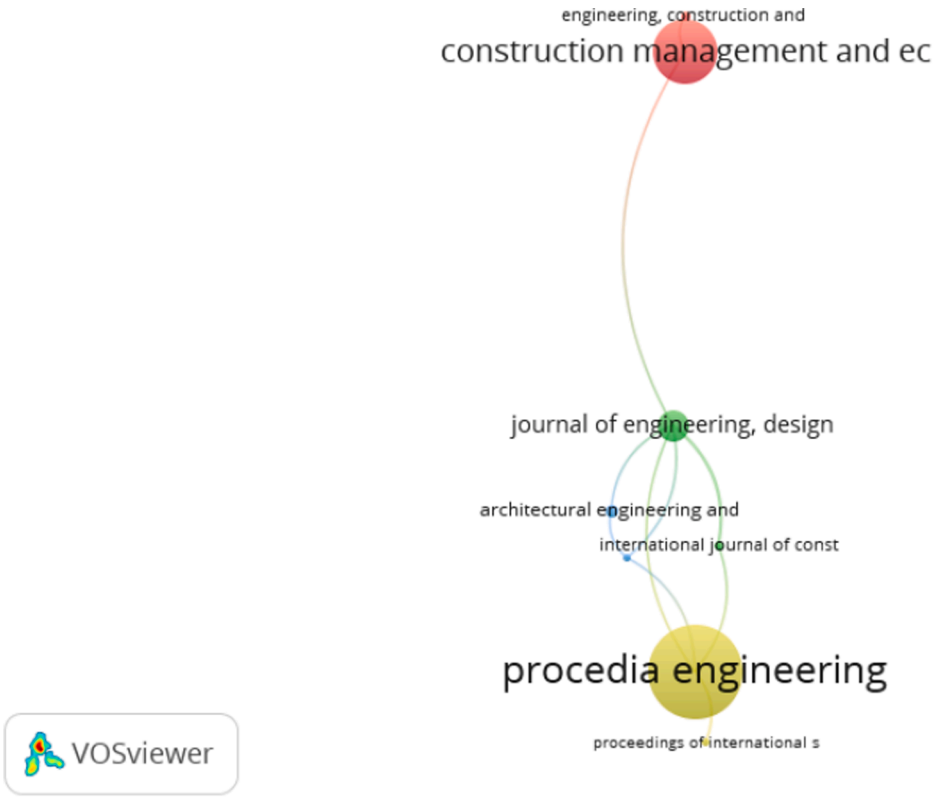


Fig. 9. Visualisation of association strength citation analysis of mainstream journals and conferences in construction H&S in DCs: citation analysis.

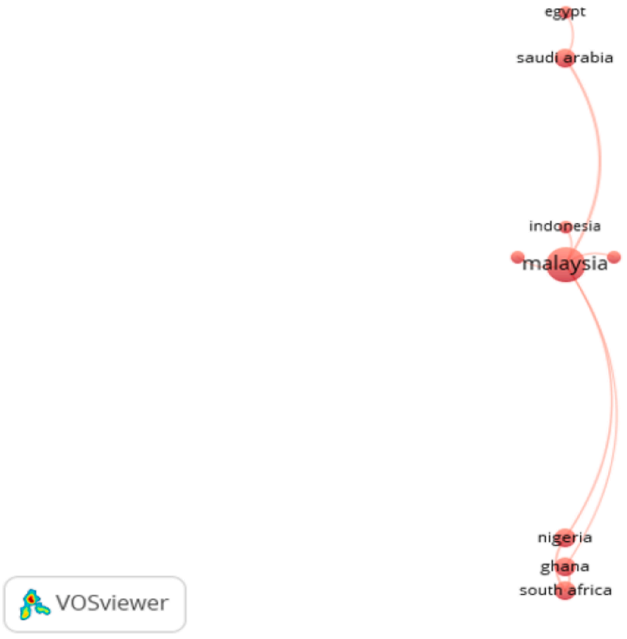


Fig. 10. Visualisation of co-authorship by country.

normalisation addresses this. By implication, the normalisation citation in Table 5 is not biased by the duration of the publications. Table 5 demonstrates that a high number of publications does not mean a high citation impact. It also shows that the higher citations do not mean higher impacts through average normalised citations. For example Smallwood has 48 citations in 13 documents but has the average normalised citations 1.20, ranking 6th based on this.

Table 4
Quantitative analysis of co-authorship analysis by country.

Country	Total link strength	documents
Malaysia	10	71
South Africa	5	68
Nigeria	5	20
Saudi Arabia	5	12
Ghana	3	7
Iran	1	13
India	1	35
Indonesia	1	23
Egypt	1	12

4.3.3. Citation analysis of documents

The rationale for citation analysis of authors is applicable here. Citation analysis of documents (journal articles and conference proceedings papers) indicates their impact on the H&S scientific community (Bornmann and Wohlrabe 2019; Martin and Irvine 1983; Aksnes et al., 2019). A threshold of 5 was set as the minimum number of citations of a document to be included in the analysis. Of the 510 documents, 101 met it hence used. The citation analysis of journal and conference papers (the main ones) are presented in Table 6 and the association strength analysis in Fig. 13. Fig.13 and Table 6 indicate the impact (usefulness, accuracy, and importance) of the publications (Bornmann and Wohlrabe 2019; Martin and Irvine 1983; Aksnes et al., 2019). Using normalisation citations, it is evident in Table 6 that Guo et al. (2020) have the highest impact. Again, older documents are likely to have more citations than the recent ones hence normalisation addresses this misinterpretation (Van Eck et al. 2017). This means that, for example, Guo et al (2020) which is a recent publication has the same opportunity as older ones such as Kartam (1997). Further, Aminbakhsh et al. (2013) have the highest number of citations but second to the highest normalised citation. The methodology of the study, Analytic Hierarchy Process (AHP), is consistent with the author keyword analysis where it has the highest

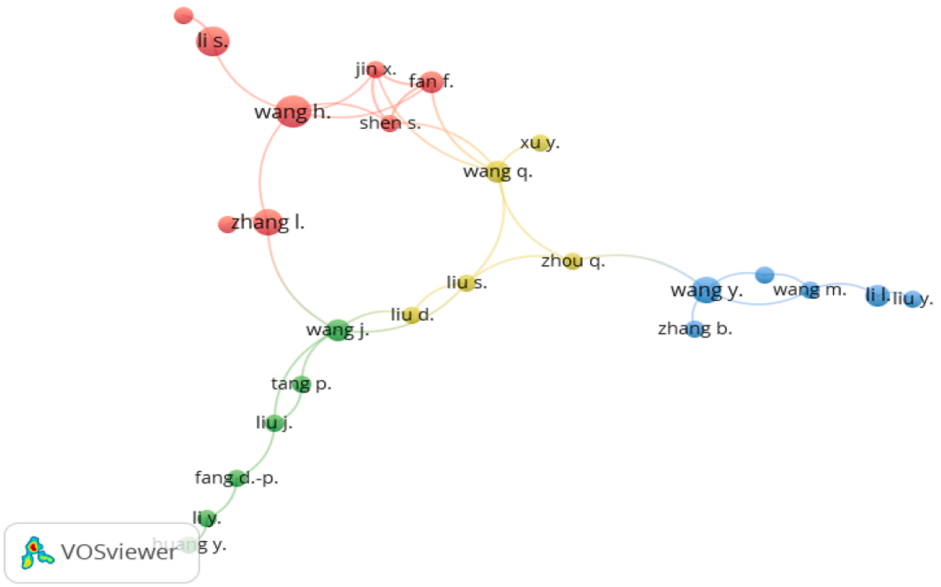


Fig. 11. Visualisation of co-authorship by authors.

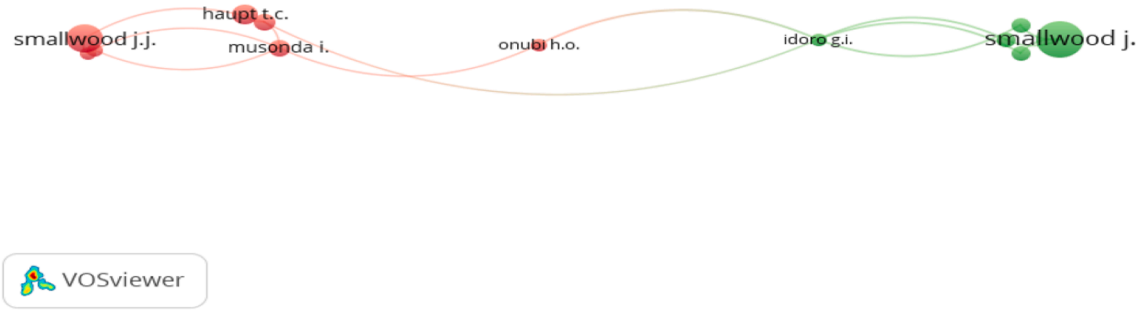


Fig. 12. Network visualisation of the main citation relationship among the main authors.

Table 5
Quantitative summary of author impact in construction H&S research in DCs.

Author	Total Link Strength	Documents	Citations	Average publication year	Average citation	Normalised citation	*Average normalized citations
Idoro G.I.	9	3	33	2010	26.00	8.04	2.68
Simpeh F.	5	3	6	2021	1.33	7.00	2.33
Amoah C.	5	3	4	2021	1.33	7.00	2.33
Musonda I.	4	5	0	2017	2.00	11.66	2.33
Onubi H.O.	3	3	18	2020	2.00	5.13	1.71
Smallwood J.J.	5	13	48	2010	5.15	1.20	1.20
Haupt T.C.	1	7	6	2011	4.71	8.00	1.14
Aigbavboa C.	4	5	11	2017	2.20	2.39	0.48
Yatim Y.M.	4	4	5	2020	0.00	0.00	0.00
Mahmoud A.S.	4	4	1	2020	00.00	0.00	0.00

*'Average normalised citation is the average nornalised number of citations received by the documents in which a keyword or term occurs or the average normalised number of citations received by the document published by a sources, an author, organization, or a country' (van Eck, and Waltman 2021: 37).

level of impact (Table 2). Also, risk assessment, the focus of Aminbakhsh et al. (2013), is also a major author keyword in Table 2 and Fig. 8.

To understand the impact that each country examined makes, the citation analysis by country was conducted. A threshold of a minimum of one document per country was set for it, and 52 countries met it. However, after further examination, some countries and words such as 'technology' and 'P', which should not be on the list were removed hence only 43 countries were used. For the association strength analysis of countries, 13 of them have the level of connection that can be represented graphically hence in Fig. 14 and their average publication year, average citations and average normalised citations as per countries are in Table 7. While South Africa has the highest link strength, they do not have the highest average normalised citation. The countries with higher average normalised citations are likely to have a higher impact on the construction H&S research community. Table 7 shows that a high number of citations or documents does not mean a higher average normalised citation as in the cases China and South Africa.

5. Discussions

The fluctuating pattern in construction H&S research in DCs in Fig. 2 is consistent with the pattern of construction safety research globally as

Table 6
Summary analysis of publication impact in construction health and safety in developing countries, highly cited documents.

Article	Title	Citations	Normalised citations	links
Guo et al. (2020)	The dust diffusion modelling and determination of optimal airflow rate for removing the dust generated during mine tunnelling	25	16.91	0
Aminbakhsh et al. (2013)	Safety risk assessment using analytic hierarchy process (AHP) during planning and budgeting of construction projects	183	16.21	2
El-Mashaleha et al. (2010)	Utilizing data envelopment analysis to benchmark safety performance of construction contractors	79	11.62	0
Abrey and Smallwood (2014)	The effects of unsatisfactory working conditions on productivity in the construction industry	24	6.68	1
Idoro. (2008)	Health and safety management efforts as correlates of performance in the Nigerian construction industry	36	4.26	1
Mete et al. (2019)	A decision-support system based on Pythagorean fuzzy VIKOR for occupational risk assessment of a natural gas pipeline construction	24	3.82	1
Smallwood (2004)	The influence of engineering designers on health and safety during construction	25	3.12	0
Jannadi and Bu-Khamsin (2002)	Safety factors considered by industrial contractors in Saudi Arabia	64	3.07	1
Aksorn & Hadikusumo (2008)	Measuring effectiveness of safety programmes in the Thai construction industry	25	2.96	0
Bahrainy and Khosravi (2013)	The impact of urban design features and qualities on walkability and health in under-construction environments: The case of Hashtgerd New Town in Iran	33	2.92	0
Idoro (2011)	Comparing occupational health and safety (OHS) management efforts and performance of Nigerian construction contractors	30	2.70	2
Janackovic et al. (2013)	Selection and ranking of occupational safety indicators based on fuzzy AHP: A case study in road construction companies	25	2.21	0

Jin et al. (2019a) report. This includes the extremely limited research before 1994 in the figure; in Jin et al. (2019a), only 10 studies were published before 1990 and 10 from 1991 and 1995. Nevertheless, given that journals and conferences were reviewed in the current study, it can be argued that the number of publications in DCs is limited in number over the 30.5 years. Worse still, of the 152 countries named as developing by IMF (Worlddata, 2020), only 43 had at least one journal and/or conference publication in construction H&S in Scopus. Given that Scopus has a more recent and broader range of journals than Web of Science (Aghaei Chadegani et al. 2013; Vieira and Gomes 2009) and conference proceedings were considered in this review, there is strong evidence that DCs are lagging behind in H&S. Further, drawing on Table 7, it is evident that majority of the publications re from China, the highest, followed by Malaysia (with 71) and South Africa 68. Brazil has 44 and India has 35. Eighteen countries such as Vietnam, Kenya, Peru, Iraq, Yemen, and Qatar have just one publication and twelve countries have between 2 and 5 publications. This shows limited attention to construction H&S in many countries.

Further, the findings show that three authors have over 10 publications on construction H&S namely Emuze F., Latief Y., and Smallwood J. J., the highest. However, of these three, only Smallwood made an impact based on average normalised citations. Other authors with an impact based on average normalised citations are Idoro G. I. (the highest), Simpeh F., Amoah C., Musunda I., Onubi H. O., Haupt T. C., and Aigbavboa C. (Table 5).

Nevertheless, the conclusion about scholarly impact must be with caution because of the many limitations of bibliometrics and other factors.

First, using the number of publications in the analysis leaves new scholars in the discipline disadvantaged and the older ones therein advantaged (Grinäv 2020). It is unable to differentiate between types of research outputs (Choudhri et al. 2015). Hence, it has not been used in the current study but just presented.

Second, the citation indicators (average citations, citations, normalised citations, average normalised citations) are based on their counts and have been criticised by authors as unreliable (Belter 2015; Choudhri et al. 2015; Open University 2021; Grinäv 2020). They do not solve the problem of self-citation abuse (Grinäv 2020; Choudhri et al. 2015), authors can be cited for many reasons and the indicators are unable to consider the positive and negative ones hence all are counted as a credit to the authors (Choudhri et al. 2015). In particular, the various reasons for citations include crediting a mentor/expert in the field, criticising a flawed methodology, supporting points in the text, discussing misleading results (Belter 2015), for a personal relationship with the author being cited, and even increase citation count of citing the author (Choudhri et al. 2015). Bibliometric indicators are still unable to detect such variations and consider them (Belter 2015).

Third, citation indicators are unable to measure real-life impact such as if the research cited improved lives (Belter 2015). It does not consider other indicators that demonstrate academic impact.

Fourth, there some publications in renowned H&S conferences such as CIB W099 which are not indexed in Scopus hence not in this study. By implication, some papers from key authors in H&S such as Smallwood J. J., and Haupt T. C. who have made impacts as past CIB W099 co-ordinator (a working commission focused on construction H&S with a regular conference on topics in the subject) and graduated a lot of PhD in H&S are unaccounted. Hence, this indicates that Table 5 is not a true reflection of impact.

Lastly, some of the scholars in DCs in the area are not in the current study, for example, Umeokafor N. and Manu P. Also, authors such as Chan, A. P. C. with a high number of publications in construction safety in Jin et al. (2019a) are not found in the current study because their country of institution affiliation, for example, Hong Kong, is not defined as a DC by IMF (Worlddata, 2020).

In conclusion, citation counts are limited in the indication of impact (Belter 2015). Consequently, they can only measure the usefulness or impact of the papers to the authors (that is those that cite them), nothing else (Belter 2015). The citations says very little as it does not show if the papers report on a ground-breaking project, programme, or give idea that there is strong evidence of its direct impact on the H&S of people in the industry and country (Grinäv 2020). Consequently, papers with high citation indicators such as average normalised citations would need to be examined in detail by the readers to make an informed decision. The

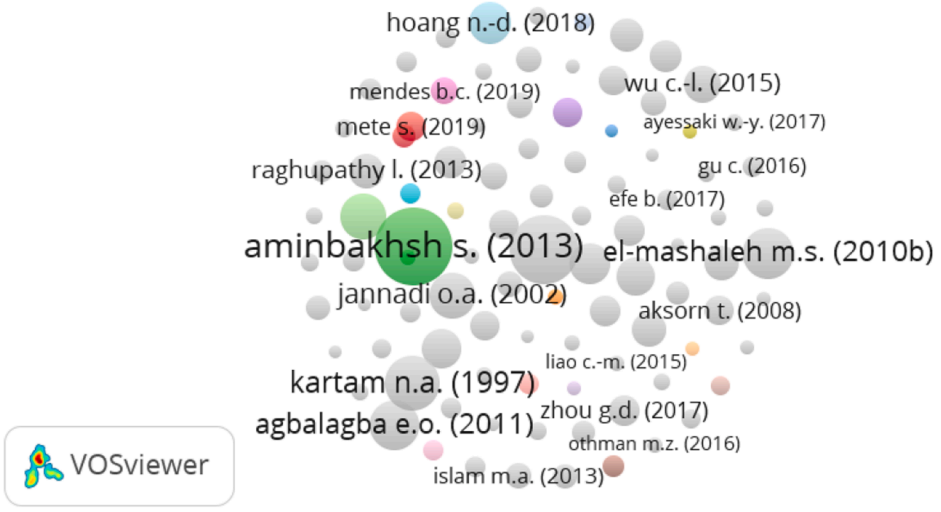


Fig. 13. Citation association strength analysis of journal and conferences articles.

Fig. 14. Visualisation of country relationship by citations.

Table 7
Quantitative summary of impact of countries based on citations.

Country	Documents	Citations	Average publication year	Average citations	Average normalised citations	Total link strength
Jordan	5	102	2014	20.40	3.64	2
Turkey	20	362	2016	18.10	2.81	2
Palestine	1	3	2020	3.00	2.03	1
Nigeria	20	191	2016	9.55	1.57	19
Iran	13	90	2014	6.92	1.42	1
Thailand	7	49	2015	7.00	1.37	2
Egypt	12	81	2015	6.75	1.30	3
China	118	543	2014	4.60	1.24	2
South Africa	68	260	2013	3.82	0.92	24
India	35	160	2015	4.57	0.83	1
Saudi Arabia	12	216	2014	18.00	0.69	7
Indonesia	23	77	2017	3.35	0.67	1
Malaysia	71	200	2014	2.82	0.63	17
Ghana	7	14	2019	2.00	0.49	2

Note: Presents only the countries with data on all six indicators hence 14. Those excluded had did not have enough strong connections.

relevance to the publications to addressing DCs' H&S issues needs to be a priority. Nevertheless, citation indicators for keywords and countries say more in that they show where the attention of the examined publications lies.

Fig. 9 shows that scholars in construction H&S in DCs mainly publish in conference proceedings, with 'Iop Conference Series: Materials Science and Engineering' having the highest number of publications which is consistent with the finding of Umeokafor (2018). However, the dominant journal, according to the association citation strength analysis (Fig. 9), is 'Construction Management and Economics' and the second most impactful (with average normalised citations 2.91) while Architectural Engineering and Design Management has the highest average normalised citations of 3.43 (Table 3). This is encouraging as these are high ranking journals. However, conference publications in Procedia Engineering have the highest number of citations (Table 3), suggesting that it is a high attraction outlet for scholars in DCs. Conference organisers may find this helpful, perhaps an attractive advertising strategy.

However, using the citation indicator to measure impact has limitations. For example, journals can game metrics through ways that can artificially boost their score in bibliometrics (Open University 2021). One example is that they expect authors or even tell them to cite

publications in the journal in the manuscript submitted. By implication, this increases the chance of acceptance in the journal.

5.1. Summary of major research topics in construction H&S research in DCs

Contrary to the expectation of Umeokafor et al. (2020) that construction H&S research in DCs focuses on the first two phases (but mainly on the first) of the three phases of the evolution of safety culture by Pybus (1996), the attention of scholars therein seems to cut across the three Phases. The first phase is 'traditional', involving attention to discipline and enforcement, individual control and focus on the high effects of injury risks. In the current research, this applies to the attention on accidents, risk-related studies, regulation and compliance (Tables 1 and 2). This is emphasised in the author keywords analysis, ranking the second, third and sixth highest (Table 2). However, the second phase, transitional, which entails engineering controls hence addresses health issues, employee training programmes, and attention to safe work procedures is mainly reported in Table 1, all keywords analysis. Here safety management and safety performance are emphasised. The last phase, innovation (the modern stage), records the highest in Table 1. Examples of this include human-related factors including human behaviours. In this phase, Pybus shows that occupational health and safety are integrated into decision making, there is an emphasis on the elimination of risk through strategies such as DFS (which is still limited in DCs as found in this study) and a focus on cultural and motivational issues. While being at the third stage is encouraging, there are counter-productivity implications. For example, many DCs are still at the first phase as their contexts require. If phase three strategies and techniques are introduced therein, the environments may be unable to accomodate such because of several limitations hence likely to be ineffective and inefficient. In particular, introducing DFS in a country where there are no legislation and poor enforcement of the existing ones, getting the relevant support from stakeholders like the client to enable the designers to design out the hazards may be challenging. According to Finneran and Gibb (2013), going through these phases one after the other is expected; missing one has implications for the evaluation of safety culture. Hence, the first stage is fundamental (Umeokafor et al 2020). Adopting digital technologies in H&S on construction sites where there is unsteady power supply, poor internet, and no or weak data privacy laws impacts the effectiveness and efficiency of the technologies and strategies. This suggests that the countries in the third phase may be the more developed ones. The analysis does not affords the opportunities to examine this.

The consistency between the high impact publications (El-Mashaleha et al. 2010; Abrey & Smallwood 2014) in H&S research (Table 6) and the main research focus, risk-related studies, and productivity (Table 2) offer strong evidence to conclude the focus of the construction H&S research in DCs. However, the extant research does not adequately meet the needs of the regions. For example, religion is not adequately considered by academics in research despite its high level in DCs. This calls for attention. This is exacerbated by the over-representation of some topics such as accidents and risk assessment, but contextual issues-related studies are a few and the research by the few countries limited to quantitative methods. The need to ensure that the recommendations of research in DCs address relevant issues therein is noted in ElSehaimi et al. (2013). ElSehaimi et al. (2013) found that some recommendations by studies in such countries fail to address the issues in DCs because of the poor research methods and strategies. Health and safety issues are context-based which qualitative methods excel in addressing (Kheni 2008) as they can ensure close collaboration with industry partners to generate new knowledge, models, and frameworks (ElSehaimi et al. 2013). The topics with high citations or attention in the current study present the risk of being misconstrued as a favourable or attractive area hence drawing the attention of academics to increase their citation 'impact' (Open University 2021). This is unprofessional and discouraged; the direct impact of improving H&S based on the needs of countries and industries must guide academics.

Comparing the research focus of scholars in DCs to Jin et al. (2019a) who examine construction safety research globally, it is evident that the findings of the current study is different from the global focus to some extent. For example, Jin et al (2019a) found that leading indicators such as safety climate are highly studied globally, but this is underexamined, a finding in the current research. This suggests that the attention is likely from developed countries. Jin et al. (2019a) also found that stimulation and fall from height are highly examined keywords. But the evidence in the current study demonstrates that stimulation and fall from height studies are not the focus of construction H&S academics in DCs. Possible explanations for such are the differences in contextual needs, and that conference papers, a major publication outlet of scholars in DCs, were examined in the current research but not in Jin et al (2019a).

5.2. Selected main knowledge gaps in construction health and safety in developing countries

This extensive review demonstrates plenty significant knowledge gaps in construction H&S research in DCs. While the readers can interpret the findings to suit their various research needs, selected gaps are highlighted and/or demonstrated below. These are informed by drawing on Tables 1 and 2 and Figs. 3–8. The details of the associated studies therein were obtained from the bibliometric analysis data imported into VOSViewer. Where possible, examples of associated papers are cited and discussed with supporting literature.

Regulation and compliance in construction H&S. The limited research on this topic is consistent with the findings of Suárez Sánchez et al. (2017) (although focussing on construction H&S research globally) where 21 papers (7.5 per cent) of the 285 examined focus on H&S regulation in construction. The extant studies here are not limited to the complex regulatory frameworks in H&S (Umeokafor et al. 2019), assessment of H&S in construction (Eyiah et al. 2019 for Ghana, and Windapo and Oladapo (2012) for South Africa), and strategies for improving H&S regulations in construction (Elsebaei et al. 2020; Umeokafor et al 2020). In the current study, evidence shows limited research in the understanding the regulatory environments in specific countries, establishing the impact of regulation in improving H&S in DCs, and regulatory implications in digital technologies application in H&S.

Qualitative research in H&S. The research shows that questionnaire surveys and AHP are the dominant research methods adopted in construction H&S research in DCs (Table 1 and Fig. 3, Table 2 and Fig. 8). This is consistent with Umeokafor and Windapo (2018) who found that qualitative research is underrepresented in built environment research. Also, Bubaker et al. (2005), Crossley and Vulliamy (1996), Hughes (2010), and Laryea and Leiringer (2012) report a strong culture of quantitative research in construction management research in DCs.

Risk assessment/management. The abundance of research in this area is in Tables 1 and 2 and Fig. 3 and 8. It is consistent with the findings of Suárez Sánchez et al. (2017) (although focussing on construction H&S research globally) where 101 papers (35.4 per cent) of the 285 examined focus on risk assessment in construction. In the current study, this is an area examined in various ways, for example, risk matrix (Ranjan et al. 2019), and occupational health and safety risks in construction (Amin et al. 2019) (in Tables 1 and 2; Fig. 8, and the bibliometric analysis data). But there are insufficient studies on the risks that ICT poses to construction safety in DCs (such data security), the risk from interactions between humans and technologies, and strong evidence of risk assessment improving safety performance in construction.

Safety management. This is extensively covered in research as shown in Figs. 4–7 and Table 1 with specific examples of studies including Idoro (2008), Aksorn and Hadikusumo (2008), Aghimien et al. (2019), Okonkwo and Wuim (2020) and Ammad et al. (2020). However, the role of digital technologies such as internet-of-things in safety management

(Jin et al. 2019a), safety programs in occupational health and safety management in specific DCs (Umeokafor, 2017) and the role of leadership in H&S management in construction require further exploration.

Design for Safety. Given that in DFS or prevention through design, the hazards are designed out at the pre-construction stage, it is one of the proactive measures for improving H&S. The current study in Table 1 suggests that this is underexamined in DCs where the keywords occurrence is 13 and average normalised citation, 0.75. This knowledge gap is evident in Poghosyan et al. (2018) and most of the extant studies in DFS are in developed countries. Selected specific gaps in DCs include DFS opportunities (Umeokafor et al. 2021), the motivations and attitudes of designers toward DFS (Manu et al. 2018), legislative issues in DFS (Manu et al 2019) and understanding DFS from the interpretivist and constructivist perspective (Umeokafor et al. 2021). DFS skills, knowledge and attributes will require further examination, especially using qualitative research methods. Most of the few studies found focus on Malaysia, two in Ghana and Nigeria respectively, and a few in South Africa. More specific country research on DFS is also needed.

Digital technology/industry 4.0 technologies and H&S. Improving construction H&S using digital technology is increasing (Hou et al. 2021), but the current study shows that it is underexamined in DCs as suggested in Tables 1 and 2 and Figs. 3 and 8 where the core associated studies do not meet the selection criteria to be highlighted in the findings. This finding is supported by Guo et al. (2017), a review of digital technologies for construction safety in 14 high-ranking journals from 2000 to 2016. They found that while China ranks second with 31 publications, other countries, India, Iran, Pakistan, Romania, and Thailand all ranked low, with one publication each. The specific gaps in knowledge here include the adoption and implementation of digital technologies in construction forms and projects (Guo et al. 2017), strong evidence of digital technologies improving safety performance (Guo et al. (2017), challenges in using digital twins in construction safety such as a mechanism for providing safety information to construction workers by technical means (Hou et al. 2021), and the implications of the social, political, cultural and social context on digital technologies applications in construction safety. The role of leadership in digital technologies in construction safety, and ontology and H&S also need some attention.

Contextual influences in construction H&S. One of the motivations for this research is that the contexts of DCs are different from their developed counterparts (Umeokafor et al. 2019). Consequently, the challenges they encounter, just as the solutions, will be different from their developed counterparts and these must be rooted in these contexts to ensure that they are fit for purpose (Kheni et al., 2010; Nuwayhid, 2004). However, the associated studies do not meet the criteria to be highlighted in the findings of the current study, suggesting knowledge gaps which is consistent with Kheni et al., (2010); Nuwayhid, (2004) and the findings of Umeokafor (2018).

Hazards and site safety. Having received significant attention (see Section 4.1.4), there is still the need to explore how digital technologies such as virtual and augmented reality can facilitate this. This will also cover how they can be used in training. Wearable technologies in construction safety, using digital technologies in designing out hazards (Jin et al 2019a), applications of drones for inspections and monitoring construction sites, and DCs specific challenges in their adoption need further examination.

Procurement practices and health and safety. This topic is underexamined. Based on the data from the bibliometric analysis, the focus of the studies that examine it in the current study are contract documents in H&S management (Sulaiman et al. 2008), including H&S in contracts documents such as bill of quantities (Smallwood and Emuze 2014); and a mathematical model that can predict significant potential contracts risks (such as those from health, safety and welfare) at the tendering stage (Samuel 2014). Early consideration of occupational health and safety in procurement, adopting technology to improve H&S in procurement, strategies for improving H&S in different types of procurement (especially the emerging ones such as direct labour and labour-only) need to be examined. The role of stakeholders in H&S decision-making in construction procurement is also overlooked.

Accident prevention. This is another well-researched area (see Figs. 3–7 and Table 1) which is consistent with the findings of Suárez Sánchez et al. (2017) where 83 of the 285 papers (29.1 per cent) examined are on accident analysis. Accident-related studies are documented in the results section of this paper, for example, the accident analysis of the industry (Abdullah and Wern 2011) and underreporting of accidents (De Silva et al., 2018) (see results for details). However, more attention from a country-specific perspective on the underreporting of accidents, its causes, how digital technology can help improve it and the alternatives to accident reporting using digital technologies is required. However, this area is over-researched just as risk-related research in construction.

Construction H&S education and training. This area is highly underexamined (c.f Tables 1 and 2 where they do not meet the threshold to be highlighted but are in the bibliometric analysis data). While Suárez Sánchez et al. (2017) review construction H&S from the global perspective, this finding is consistent with theirs where 22 of the 285 papers (7.7 per cent) examined focus on construction H&S education and training. The extant research in the current study centre on DFS education in Malaysia (Che Ibrahim et al. 2021), safety education programme for handling equipment used to handle materials in construction sites in India (Kumar et al. 2013), skills and knowledge competency for health and safety induction training in Nigeria (Okorie & Musonda 2020), and the role of universities in H&S (Sisli 2019). In India, the transfer of safety training skills is covered in Rajaprasad and Chalapathi (2016). In Indonesia, the model for learning/training of construction H&S is examined by Endroyo et al. (2015). Focusing on Malaysia, Teck et al. (2015a) address construction safety training methods; and in the same country, construction safety induction is covered in Teck et al. (2015b). Consequently, it is logical to conclude that there are several knowledge gaps in this topic. For example, the contextualisation of construction safety curricula and the extent to which the characteristics of the industry impact construction safety education, training, and curricula in DCs need to be examined. The role of professional bodies in construction safety education, and how regulation can influence them also require further examination.

Safety climate and culture. Suárez Sánchez et al. (2017) review construction H&S research globally and found that only a few publications focus on this area. Based on the bibliometric analysis data, this is consistent with the current research. In particular, the extant studies found in the current study include Musonda et al. (2021) where how to measure and improve safety cultures in organisations is explored in South Africa and Williams et al (2020) where construction of H&S culture maturity is assessed in Ghana. The knowledge gaps on this topic are not limited to the need to explore the influence of digital technologies on safety culture and climate improvement and measurement. The state of H&S culture in construction and their maturity ladder would need exploration in many DCs, following on from Williams et al (2020) who focus on Ghana.

Based on the researchers' experience and data from the bibliometric analysis, other areas in construction H&S that require more attention are not limited to: Skill and Knowledge transfer; skills and knowledge requirements for H&S professionals; social support for the mental health of construction workers; behavioural safety; safety performance indicators; equality, diversity and inclusion in H&S including mental health; worker engagement in H&S management in some of the countries; and sustainable cities for improving H&S.

5.3. *Direction of future research in construction health and safety in developing countries*

Drawing on the keyword clusters, keywords, research topics and knowledge gaps, the following are the suggested directions of future

research in construction H&S in DCs.

- Attention to accident prevention will continue to increase but focus on the adoption of technology in accident prevention and causation is likely to gradually gain momentum.
- Sustainable construction and development through occupational health and safety are likely to increase with more studies drawing on sustainability indicators and sustainable development goals.
- While missing any of the phases of the evolution of safety culture has implications for safety culture, it is indicative that more studies will focus on the innovative strategies whereas their contexts may be more favourable to traditional or transitional phase.
- There is likely to be an increase in pre-construction safety strategies where studies will focus on using technology to design for safety, preventing accidents, health monitoring, ergonomics and other human-factors related issues including behavioural safety.

6. Study implications

- The implications of the study focussing on DCs are that the differences between the countries in terms of H&S is evidenced, demonstrating that some countries (for example those in the Caribbeans) experience underrepresentation of construction H&S research than others. Academics can now see possible areas of research in their countries. Also, the specific research gaps, trends and needs in DCs in construction H&S research are now evident as against the generic or global ones in Jin et al. (2019a). It also shows the difference in construction H&S research interest and attention between DCs and developed countries, calling for more DCs context-based studies. This is pertinent for adequately addressing issues in the countries and ensuring the solutions are fit for purpose.
- The co-authorship relationship implies that the geographic locations of the authors may be a motivation for co-authorship, the closer author the more likely they are to co-author construction H&S papers.
- The growing attention in construction H&S research which is skewed to selected countries with emphasis on China, Malaysia, South Africa and Brazil means that many DCs are left behind in occupational health and safety.
- The high concentration of in conference proceedings papers suggests the dominant outlet of construction H&S scholars in DCs, highlighting the need for review research in the areas of construction H&S, construction management and construction project management to include such outlet to ensure that the views of the countries are captured. However, the need to encourage the scholars in these countries to channel their research into journals is also highlighted as a result.
- The complementary outcome of using author keywords and all keywords in the analysis offers unique insight into research trend identification suggesting the need for other review papers to consider this.

7. Conclusions

This comprehensive review examines the characteristics of construction safety and health research that focus on DCs which are published in journals and conferences proceedings indexed in Scopus from 1990 to 2021. Using bibliometric and scientometric analyses, there is evidence that the H&S scholars in the countries have paid more attention to safety management, accident-related matters, human-factor research, and risk-based/related studies in construction. There are several knowledge gaps in construction H&S in the areas of digital technologies, contextual issues, regulation and compliance, procurement, DFS, social support and mental health, and skills and knowledge requirements for H&S professionals. Despite the dearth of construction H&S research in DCs, the little extant ones mainly come from China, South Africa, Malaysia, and Brazil and scholars mainly prefer to publish in conference proceedings than journals. However, the publications have increased over the years but has been fluctuating. The citations and documents in journals have a strong positive correlation, and a linear relationship was also observed between the keywords occurrences and their total strength.

7.1. Study contributions

Methodologically, the adoption of the scientometric approach and Bibliometrics in examining construction H&S research in developing countries addresses the limitations of the traditional method of review such as bias (subjectivity). It enables in-depth and sophisticated analysis and discussion of literature and visualisation. The theoretical contributions, extensive and specific mapping of CHS research focuses on DCs, the knowledge gaps and implications. This is the first extensive mapping of construction H&S research that focuses on the countries. Practically, attention has been drawn to the status of construction H&S research in DCs including the skewness of the little extant research in a few countries hence the research divide. Grey areas in H&S research are highlighted to academics.

7.2. Limitations and recommendations

Limiting the bibliometric search to specific DCs means that construction H&S publications which do not have names of countries in them were omitted. However, the effort of reading some of the abstracts helped include some that 'slipped' out of the search output. This is reasonable as abstracts should mention the country of data collection hence the chances of this omitting a lot is limited. While there is no limitation free method of assessing the impact of authors, the downsides of bibliometrics and scientometrics are discussed in detail in the paper. Hence, a few of the findings are indicative with further assessment by the readers recommended. The differences in construction H&S research focus in DCs has implications for the evolution of the safety culture. The analyses in the current study have not provided the opportunities to examine this, hence a recommendation for further studies. The study has not assessed the bibliographic coupling of authors, citations and documents, further studies can do this. Given the inconclusive finding on the impact of scholars because of the limitations in the indicator, further studies can address this by developing a robust framework for assessing the impact of scholars which considers numerous factors such as the relevance of publications.

CRediT authorship contribution statement

Nnedinma Umeokafor: Visualization, Software, Methodology, Formal analysis, Conceptualization, Data curation, Investigation, Project administration, Validation, Writing – original draft, Writing – review & editing. **Tariq Umar:** Writing – original draft, Writing – review & editing. **Konstantinos Evangelinos:** Writing – original draft, Writing – review & editing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

References

Abas, N.H., Jalani, A.F.A., Affandi, H.M., 2020. Construction stakeholders' perceptions of occupational safety and health risks in Malaysia. Int. J. Sustain. Construct. Eng. Technol. 11 (1), 300–311.

Abdullah, D.N.M.A., Wern, G.C.M., 2011. An Analysis of Accidents Statistics in Malaysian Construction Sector. International Conference on E-business, Management and Economics IPEDR, IACSIT Press, Hong Kong, 3, 1-4.

Abrey, M., Smallwood, J.J., 2014. The effects of unsatisfactory working conditions on productivity in the construction industry. Proc. Eng. 85, 3–9.

Adjei, K.O.K., Owusu-Ansah, C.M., 2016. Publishing preferences among academic researchers: implications for academic quality and innovation. Library Philosophy Pract. (e-journal) 1349, 1–15.

Aghaei Chadegani, A., Salehi, H., Md Yunus, M.M., Farhadi, H., Fooladi, M., Farhadi, M., Ale Ebrahim, N., 2013. A comparison between two main academic literature collections: Web of science and scopus databases. Asian Social Sci. 9, 18–26.

Aghimien, D., Aigbavboa, C., Thwala, G., Thwala, W., 2019. Critical Drivers for Health and Safety Management among SMEs in the Eswatini Construction Industry. IOP Conference Series: Materials Science and Engineering 640. https://doi.org/10.1088/1757-899X/640/1/012005.

Agyekum, K., Ghansah, F., Tetteh, P., Amudjie, J., 2020. The role of project managers (PMs) in construction health and safety implementation in Ghana. J. Eng. Design Technol. 19, 245–262. https://doi.org/10.1108/JEDT-04-2020-0122.

Akawi, J., Musonda, I., 2021. Costing of Health and Safety Elements in Construction Projects in Gauteng, South Africa. In: Collaboration and Integration in Construction, Engineering, Management and Technology. Springer, Cham, pp. 315–320.

Aksnes, D.W., Langfeldt, L., Wouters, P., 2019. Citations, Citation Indicators, and Research Quality: An Overview of Basic Concepts and Theories. *SAGE Open*, 1–17.

Aksorn, T., Hadikusumo, B., 2008. Measuring effectiveness of safety programmes in the Thai construction industry. Construct. Manage. Econ. 26, 409–421. https://doi.org/10.1080/01446190801918722.

Alara, S.A., Inuwa, I.I., Gambo, N., 2019. Application of semiotics for health and safety signs comprehension on construction sites in Yola metropolis, Nigeria. IOP Conference Series: Materials Science and Engineering 615 (1), 1–9.

AlSehaimi, A., Koskela, L., Tzortzopolulos, P., 2013. Need for alternative research approaches in construction management: case of delay studies. J. Manage. Eng. 29 (4), 407–413. https://doi.org/10.1061/(ASCE)ME.1943- 5479.0000148.

Amin, M., Abas, N., Deraman, R., 2019. The Effect of Prefabricated Steel Framing System Towards Construction Occupational Safety and Health (OSH). IOP Conference Series: Materials Science and Engineering 601 (1), 1–10. https://doi.org/10.1088/1757-899X/601/1/012035.

Aminbakhsh, S., Gunduz, M., Sonmez, R., 2013. Safety risk assessment using analytic hierarchy process (AHP) during planning and budgeting of construction projects. J. Saf. Res. 46, 99–105.

Ammad, S., Alaloul, W.S., Saad, S., Qureshi, A.H., Altaf, M., Mohsen Mohammed, A.A., 2020. Evaluating Safety Attributes in Infrastructure Projects. 2nd international Sustainability and Resilience Conference: Technology and innovation in Building Designs, IEEECONF 2020; Virtual, Sakheer; Bahrain.

Apriyati, R., Latief, Y., 2020. Knowledge base integration management system quality, safety and environmental to improve organizational performance in construction company. IOP Conference Series: Materials Science and Engineering 909 (1), 012050.

Asad, M.M., Sherwani, F., Khand, Z.H., 2020. Risk factors for construction workforce safety towards sustainability. Int. J. Sustain. Construct. Eng. Technol. 11 (2), 219–224.

Ayessaki, W., Smallwood, J., 2017. Influencing Workers' Performance through Health and Safety Interventions. Proc. Eng. 182, 42–49. https://doi.org/10.1016/j.proeng.2017.03.111.

Babaii, E., Taase, Y., 2013. Author-assigned Keywords in Research Articles: Where Do They Come from? Iranian J. Appl. Linguistics (IJAL) 16 (2), 1–19.

Bahrainy, H., Khosravi, H., 2013. The impact of urban design features and qualities on walkability and health in under-construction environments: The case of Hashtgerd New Town in Iran. Cities 31, 17–28. https://doi.org/10.1016/j.cities.2013.01.001.

Belter, C.W., 2015. Bibliometric indicators: opportunities and limits. J. Med. Library Assoc. 103 (4), 219–221. https://doi.org/10.3163/1536-5050.103.4.014.

Bornmann, L., Wohlrabe, K., 2019. Normalisation of citation impact in economics. Scientometrics 120 (2), 841–884.

Bubaker, S., Balakrishnan, P., Bernadine, C., 2005. Qualitative case study research in Africa and Asia: Challenges and prospects. In: Proceedings of The. 3rd International Qualitative Research Convention, Malaysia, pp. 1–13.

Chan, A.P.C., Nwaogu, J.M., Naslund, J.A., 2020. Mental Ill-Health Risk Factors in the Construction Industry: Systematic Review. J. Constr. Eng. Manage. 146 (3), 1–28.

Che Ibrahim, C.K.I., Belayutham, S., Mohammad, M.Z., 2021. Prevention through Design (PtD) Education for Future Civil Engineers in Malaysia: Current State, Challenges, and Way Forward. J. Civ. Eng. Ed. 147 (1), 05020007.

Chinnadurai, J., Venugopal, V., Kumaravel, P., Paramesh, R., 2016. Influence of occupational heat stress on labour productivity – a case study from Chennai, India. Int. J. Prod. Performance Manage. 65, 245–255. https://doi.org/10.1108/IJPPM-08-2014-0121.

Choudhri, A.F., Siddiqui, A., Khan, N.R., Cohen, H.L., 2015. Understanding Bibliometric Parameters and Analysis. RadioGraphics 35 (3), 736–746.

Crossley, M., Vulliamy, G., 1996. Issues and trends in qualitative research: Potential for developing countries. Int. J. Ed. Dev. 16 (4), 439–448.

De Silva, N., Rathnayake, U., Kulasekera, K.M.U.B., 2018. Under-reporting of construction accidents in Sri Lanka. J. Eng., Des. Technol. 16 (6), 850–868. https://doi.org/10.1108/JEDT-07-2017-0069.

El-Mashaleha, M.S., Rababeh, S.M., Hyaria, K.H., 2010. Utilizing data envelopment analysis to benchmark safety performance of construction contractors. Int. J. Project Manage. 28 (1), 61–67.

Elsebaei, M.A., Elnawawy, O., Othman, A.A.E., Badawy, M., 2020. A framework to activate the health and safety regulations in the Egyptian construction industry. J. Eng., Des. Technol. 19 (5), 1158–1191.

Endroyo, B., Yuwono, B., Djemari Mardapi, S., 2015. Model of Learning/Training of Occupational Safety & Health (OSH) Based on Industry in the Construction Industry. Proc. Eng. 125, 83–88. https://doi.org/10.1016/j.proeng.2015.11.013.

Eyiah, A.K., Kheni, N.A., Quartey, P.D., 2019. An Assessment of Occupational Health and Safety Regulations in Ghana: A Study of the Construction Industry. J. Build. Construct. Planning Res. 7 (2), 11–31.

Fabregat-Aibar, L., Babera-Marine, G.M., Terenco, A., Pie, L., 2019. A bibliometric and visualisation analysis of socially responsible funds. Sustainability 11 (9), 2526.

Fang, Z., Tang, T., Zheng, Z., Zhou, X., Liu, W., Zhang, Y., 2021. Thermal responses of workers during summer: An outdoor investigation of construction sites in South China. Sustainable Cities Soc. 66 https://doi.org/10.1016/j.scs.2020.102705.

Finneran, A., Gibb, A., 2013. W099: Safety and Health in construction: Research Roadmap report for consultation. Retrieved on 05-08-2018 from https://dspace.lboro.ac.uk/dspace-jspui/bitstream/2134/12523/3/pub%20376.pdf.

Fonseca, B., Sampaio, R., Fonseca, M., Zicker, F., 2016. Co-authorship network analysis in health research: Method and potential use. Health Res. Policy Syst. 14 (34), 14. https://doi.org/10.1186/s12961-016-0104-5.

Gil-Leiva, I., Alonso-Arroyo, A., 2007. Keywords Given by Authors of Scientific Articles in Database Descriptors. J. Am. Soc. Inform. Sci. Technol. 58 (8), 1175–1187.

Teck, A., Abdullah Mohd Asmoni, M.N., Misnan, M.S., Jaafar, M.N., Lee Yim Mei, J., 2015a. A Review on the Effectiveness of Safety Training Methods for Malaysia Construction Industry. Jurnal Teknologi. 74 (2).

Grinäv, A.V., 2020. The Disadvantages of Using Scientometric Indicators in the Digital Age. IOP Conf. Series: Materials Science andEngineering 940 (1), 012149.

Guo, L., Nie, W., Yin, S., Liu, Q., Hua, Y., Cheng, L., Cai, X., Xiu, Z., Du, T., 2020. The dust diffusion modelling and determination of optimal airflow rate for removing the dust generated during mine tunnelling. Build. Environ. 178 https://doi.org/10.1016/j.buildenv.2020.106846.

Guo, B., Scheepbouwer, E., Yiu, K., Tak, W., Gonzalez, V., 2017. Overview and analysis of digital technologies for construction safety management. Doi: 10.29007/zvfp.

Hämäläinen, P., Takala, J., Kiat, T.B., 2017. Global Estimates of Occupational Accidents and Work-Related Illnesses. Workplace Safety and Health Institute, Ministry of Manpower Services Centre, Singapore. http://www.icohweb.org/site/images/news/pdf/Report%20Global%20Estimates%20of%20Occupational%20Accidents%20and%20Work.

Hare, B., Cameron, I., 2012. 'Health and safety gatways for construction project planning. Eng., Construct. Arch. Manage. 19 (2), 192–204.

Hou, L., Wu, S., Zhang, G., Tan, Y., Wang, X., 2021. Literature Review of Digital Twins Applications in Construction Workforce Safety. Appl. Sci. 11 (339), 1–21. https://doi.org/10.3390/app11010339.

Health and Safety Executive (HSE), 2021. Workplace fatal injuries in Great Britain, 2021. Retrieved on 1 August 2021 from https://www.hse.gov.uk/statistics/pdf/fatalinjuries.pdf.

Hughes, W., 2010. Built Environment education, research and practice: Integrating diverse interests to make an impact. In: Laryea, S., Leiringer, R., Hughes, W. (Eds.), Procs West Africa Built Environment Research (WABER) Conference, 27–28 July. Accra, Ghana, pp. 1–8.

Idoro, G.I., 2008. Health and safety management efforts as correlates of performance in the Nigerian construction industry. J. Civ. Eng. Manage. 14 (4), 277–285.

Idoro, G.I., 2011. Comparing occupational health and safety (OHS) management efforts and performance of Nigerian construction contractors. J. Construct. Dev. Countries 16 (2), 151–173.

International Labour Organisation (ILO), 2017. Nigeria Country Profile on Occupational Safety and Health 2016. Retrieved on 27 August 2018 from https://www.ilo.org/wcmsp5/groups/public/—africa/—ro-addis_ababa/—ilo- abuja/documents/publication/wcms_552748.pdf.

International Labour Orgaisation (ILO), 2018. World Statistics. Retrieved on 11th August 2018 from https://www.ilo.org/moscow/areas-of-work/occupationalsafetyandhealth/WCMS_249278/lang–en/index.htm.

Ismail, S., Che Ibrahim, C.K.I., Belayutham, S., Mohammad, M.Z., 2021. Analysis of attributes critical to the designer's prevention through design competence in construction: the case of Malaysia. Arch. Eng. Des. Manage. https://doi.org/10.1080/17452007.2021.1910926.

Janackovic, G.L., Savic, S.M., Stankovic, M.S., 2013. Selection and ranking of occupational safety indicators based on fuzzy AHP: A case study in road construction companies. South Afr. J. Ind. Eng. 24 (3), 175–189 (in this issue).

Jannadi, O., Bu-Khamsin, M., 2002. Safety factors considered by industrial contractors in Saudi Arabia. Build. Environ. 37, 539–547. https://doi.org/10.1016/S0360-1323(01)000567.

Jin, R., Zou, P., Piroozfar, P., Wood, H., Yang, Y., Yan, L., Han, Y., 2019a. A science mapping approach based review of construction safety research. Saf. Sci. 113, 285–297. https://doi.org/10.1016/j.ssci.2018.12.006.

Jin, R., Zou, Y., Gidado, K., Ashton, P., Painting, N., 2019b. A Review of BIM-based Research in 3 Construction Engineering and Management. Eng., Construct. Arch. Manage. 26 (8), 1750–1776. https://doi.org/10.1108/ECAM-08-2018-0350.

Karakus, M., Ersozlu, A., Clark, A., 2019. C (2019) Augmented Reality Research in Education: A Bibliometric Study. EURASIA J. Math., Sci. Technol. Ed. 15 (10), 1–12.

Kartam, N.A., 1997. Integrating safety and health performance into construction CPM. J. Construct. Eng. Manage. 123 (2), 121–126.

Kasirossafar, M., Ardeshir, A., Shahandashti, R.L., 2021. Developing the sustainable design with PtD using 3D/4D BIM tools. World Environmental and Water Resources Congress 2012: Crossing Boundaries, Proceedings of the 2012 Congress.

Kheni, N.A., 2008. Impact of Health and Safety Management on Safety Performance of Small and Medium-Sized Construction Businesses in Ghana. Department of Civil Engineering, Loughborough University, Loughborough. Unpublished PhD Thesis.

Kheni, N.A., Gibb, A.G.F., Dainty, A.R.J., 2010. The health and safety management within small and medium-sized enterprise (SMEs) in developing countries: study of contextual influence. J. Constr. Eng. Manage. 136 (10), 1104–1115.
Kumar, C.N., Krishnaraj, R., Sakthivel, M., Arularasu, M., 2013. Implementation of safety education program for material handling equipment in construction sites and its effectiveness analysis using T-test. Int. J. Appl. Environ. Sci. 8 (15), 1961–1969.
Kunisch, S., Menz, M., Bartunek, J.M., Cardinal, L.B., Denyer, D., 2018. Feature topic at organizational research methods: How to conduct rigorous and impactful literature reviews? Org. Res. Methods 21 (3), 519–523.
Laryea, S., Leiringer, R., 2012. Built Environment research in West Africa: current trend and future direction. In: Laryea, S., Agyepong, S.A., Leiringer, R., Hughes, W. (Eds.), Procs 4th West Africa Built Environment Research (WABER) Conference, 24–26 July. Abuja, Nigeria, pp. 797–804.
Luo, F., Li, R.Y.M., Crabbe, M.J., Pu, R., 2022. Economic development and construction safety research: A bibliometrics approach. Saf. Sci. 145, 105519 https://doi.org/10.1016/j.ssci.2021.105519.
Manu, P., Poghosyan, A., Agyei, G., Mahamadu, A.M., Dziekonski, K., 2018. Design for safety in construction in sub-Saharan Africa: a study of architects in Ghana. Int. J. Construct. Manage. 21 (4), 382–394. https://doi.org/10.1080/15623599.2018.1541704.
Manu, P., Poghosyan, A., Mshelia, I.M., Iwo, S.T., Mahamadu, A.M., Dziekonski, K., 2019. Design for occupational safety and health of workers in construction in developing countries: a study of architects in Nigeria. Int. J. Occup. Saf. Ergon. 25 (1), 99–109. https://doi.org/10.1080/10803548.2018.1485992.
Martin, B.R., Irvine, J., 1983. Assessing basic research—Some partial indicators of scientific progress in radio astronomy. Res. Policy 12 (2), 61–90.
Masuin, R., Latief, Y., 2019. Development of integration risk on integrated management system in order to increase organizational performance of construction company. IOP Conference Series: Materials Science and Engineering 620, 012024. IOP Publishing. doi: 10.1088/1757-899X/620/1/012024.
McBurney, M.K., Novak, P.L., 2002. What is bibliometrics and why should you care? In Professional Communication Conference, 2002. IPCC 2002. Proceedings. IEEE International. IEEE, pp. 108-114.
Mete, S., Serin, F., Oz, N., Gül, M., 2019. A decision-support system based on Pythagorean fuzzy VIKOR for occupational risk assessment of a natural gas pipeline construction. J. Nat. Gas Sci. Eng. 71, 102979 https://doi.org/10.1016/j.jngse.2019.102979.
Mohammadi, Amir, Tavakolan, Mehdi, 2019. Modeling the effects of production pressure on safety performance in construction projects using system dynamics. *J. Saf. Res.* 71. Doi: 10.1016/j.jsr.2019.10.004.
Moshood, T., Adeleke, A.Q., Ajibike, W.A., 2020. Human Factors Influencing Contractors' Risk Attitudes: A Case Study of the Malaysian Construction Industry. Australasian J. Construct. Econ. Build. 20, 96–116. https://doi.org/10.5130/AJCEB.v20i1.6735.
Musonda, I., Smallwood, J., 2008. Client commitment and attitude to construction health and safety in Botswana. In: Verster, J.J.P., Marx, H.J. (Eds.), Proc.: 5th Postgraduate Construction Industry Development board (cidb) conference, Bloemfontein, pp. 11–21.
Musonda, I., Lusenga, E., Okoro, C., 2021. Rating and characterization of an organization's safety culture to improve performance. Int. J. Construct. Manage. 21 (2), 181–193. https://doi.org/10.1080/15623599.2018.1512030.
Neeharika, B.L., Shishira, G., Madhuri, T.U., 2018. Some studies on occupational hazards and safety in Construction industry. Indian J. Environ. Prot. 38, 853–861.
Ning, X., Qi, J., Wu, C., Wang, W., 2019. Reducing noise pollution by planning construction site layout via a multi-objective optimization model. J. Cleaner Prod. 222, 218–230. https://doi.org/10.1016/j.jclepro.2019.03.018.
Nuwayhid, I.M., 2004. Occupational health research in developing countries: a partner for social justice. Am. J. Public Health 94 (11), 1916–1921.
Nwaogu, J., Chan, A., Hon, C., Darko, A., 2020. Review of global mental health research in the construction industry: A science mapping approach. Eng. Construct. Arch. Manage. 27 (2), 385–410. https://doi.org/10.1108/ECAM-02-2019-0114.
Oke, A., Aigbavboa, C., Ngema, W., 2017. Adoption of Smart Structures for Prevention of Health Hazards in Buildings. IOP Conf. Ser.: Mater. Sci. Eng. 269, 012064.
Okonkwo, P.N., 2019. Health and safety management and performance among construction contractors in South Africa, Unpublished Doctoral thesis. Stellenbosch University, South Africa.
Okonkwo, N.P., Wuim, J., 2020. Health and Safety Management Systems within Construction Contractor Organizations: Case Study of South Africa. J. Construct. Eng. Manage. 146 (5).
Okorie, V.N., Musonda, I., 2020. An investigation on supervisor's ability and competency to conduct construction site health and safety induction training in Nigeria. Int. J. Construct. Manage. 20 (5), 357–366. https://doi.org/10.1080/15623599.2018.1531808.
Onubi, H.O., Yusof, N., Hassan, A.S., 2020. The moderating effect of client types on the relationship between green construction practices and health and safety performance. Int. J. Sustain. Dev. World Ecol. 27 (8), 732–748.
Open University, 2021. Pros and cons of bibliometrics. https://www.open.ac.uk/library-research-support/bibliometrics/pros-and-cons-bibliometrics.
Osei-Asibey, D., Ayarkwa, J., Acheampong, A., Adinyira, E., Amoah, P., 2021. Impacts of accidents and hazards on the Ghanaian construction industry. Int. J. Construct. Manage. 1–20 https://doi.org/10.1080/15623599.2021.1920161.
Poghosyan, A., Manu, P., Mahdjoubi, L., Gibb, A.G.F., Behm, M., Mahamadu, A.M., 2018. Design for safety implementation factors: a literature review. J. Eng., Des. Technol. 16 (5), 783–797.
Pritchard, A., 1969. Statistical bibliography or bibliometrics. J. Document. 25 (4), 348–349. https://doi.org/10.1108/eb026482.
Teck, G.A., Abdullah Mohd Asmoni, M.N., Abdul Hamid, H., Misnan, M.S., YM Lee, J., Jaafar, M.N., 2015b. Evaluation Criteria of Safety and Health Induction for Construction Worker (SICW) in Malaysia. Jurnal Teknologi. 73 (5).
Pybus, R., 1996. Safety Management: Strategy and Practice. Butterworth Heinemann, Oxford.
Rajaprasad, S.V.S., Chalapathi, P.V., 2016. Quality funtion deployment method for ascertaining influential factors on transfer of safety training skills in Indian construction organizations 8. 52-61.
Ranjan, M.Z., Baharudin, B.T., Hang, T., Mahadi, M. Razif, Baharudin, M.R., 2019. Developing a Construction Occupational Safety and Health Risk Assessment Matrix (COSHRAM) with modifying risk factors. *Int. J. Recent Technol. Eng.* 8 (1C2). pp. 301-307. ISSN 2277-3878.
Samuel, D., 2014. Predicting significant contract risks at the tender evaluation stage. Proc. Inst. Civ. Eng.: Manage., Procurement Law 167 (2), 100–107.
Simpeh, F., Amoah, C., 2021. Assessment of measures instituted to curb the spread of COVID-19 on construction site. Int. J. Construct. Manage. 1–19 https://doi.org/10.1080/15623599.2021.1874678.
Sisli, Z., 2019. The role of universities in the promotion of worker protection: UCLA labor occupational health and safety program as a model for countries with developing economies. Labor History 60 (4), 309–324. https://doi.org/10.1080/0023656X.2019.1537024.
Smallwood, J., 2004. The influence of engineering designers on health and safety during construction. J. South African Inst. Civ. Eng. 46 (1), 2–8.
Smallwood, J., 2016. Designing for construction ergonomics. In: CESB 2016 - Central Europe Towards Sustainable Building 2016: Innovations for Sustainable Future, pp. 895–902.
Smallwood, J.J., Allen, C.J., Deacon, C.H., 2020. The role of industry 4.0 in construction occupational health (OH). ARCOM 2020 - Association of Researchers in Construction Management, 36th Annual Conference 2020 – Proceedings.
Smallwood, J., Emuze, F., 2014. Financial provision for construction health and safety (H&S). Construction Research Congress 2014: Construction in a Global Network - Proceedings of the 2014 Construction Research Congress. 1881 – 1890.
Smallwood, J., 2006. Scaffolding health and safety: A multi-stakeholder issue. Association of Researchers in Construction Management, ARCOM 2006 - Procs 22nd Annual ARCOM Conference, 283 – 293.
Suárez Sánchez, F.A., Carvajal Peláez, G.I., Catalá Alís, J., 2017. Occupational safety and health in construction: a review of applications and trends. Ind. Health 55 (3), 210–218. https://doi.org/10.2486/indhealth.2016-0108.
Sulaiman, K., Sulaiman, R., Salleh, H., Hashim, H.A., 2008. The potential of contract document as part of occupational safety and health management system. COBRA 2008 - Construction and Building Research Conference of the Royal Institution of Chartered Surveyors.
Tang, M., Luo, L., Chiclana, F., Zeng, X., 2018. A Bibliometric Analysis and Visualization of Medical Big Data Research. *Sustainability*, 10(1) 166. Doi: 10.3390/su10010166.
Taofeeq, D.M., Adeleke, A.Q., Ajibike, W.A., 2020. Human factors influencing contractors' risk attitudes: A case study of the Malaysian construction industry. Construct. Econ. Build. 20 (1), 96–116.
Tayeh, B.A., Yaghi, R.O., Abu Aisheh, Y.I., 2020. Project manager interventions in occupational health and safety during the pre-construction phase in the Gaza strip. Open Civ. Eng. J. 14 (1), 20–30.
Thirugnana Sambandan, V., Felix Kala, T., Nallusamy, S., 2021. Influence of cultural values on strategic and operational aspects of construction safety management in sustainable business organisations. J. Green Eng. 11 (1), P39–P53.
Tunji-Olayeni, P.F., Afolabi, A.O., Olowookere, E.I., Okpalamoka, O.I., Oluwatobi, A.O., 2019. Implications of occupational hazards on attainment of the Sustainable Development Goals in the Nigerian Construction Industry. IOP Conf. Ser.: Mater. Sci. Eng. 640 (1), 012129.
Umeokafor, N., 2017. Realities of construction health and safety regulation in Nigeria (Doctoral thesis). University of Greenwich, London, UK (in this issue).
Umeokafor, N.I., 2018. Construction health and safety research in Nigeria: towards a sustainable future. In: Saurin, T.A., Costa, D.B., Behm, M., Emuze, F. (Eds.), Proc: Joint CIBW99 and TG59 Conference, Salvador, pp. 213–221.
Umeokafor, N., Okoro, C., Diugwu, I., Umar, T., 2021, Design for safety in construction in Nigeria: a qualitative inquiry of the critical opportunities, Int. J. Build. Pathol. Adapt., Vol. ahead-of-print No. ahead-of-print. https://doi.org/10.1108/IJBPA-05-2021-0066.
Umeokafor, N.I., Evangelinos, K., Windapo, A.O., 2020. Strategies for Improving Complex Construction Health and Safety Regulatory Environments. Int. J. Construct. Manage. https://doi.org/10.1080/15623599.2019.1707853.
Umeokafor, N.I., Windapo, A.O., 2018. Understanding the underrepresentation of qualitative research approaches to built environment research in Nigeria. Int. *J. Construct. Ed. Res.* 14 (3), 198–217.
Umeokafor, N.I., Evangelinos, K., Windapo, A.O., 2019. Causal Inferences of External-Contextual Domains on Complex Construction, Safety, Health and Environment Regulation. Saf. Sci. 118, 378–388.
Van Eck, N.J., Waltman, L., 2021. VOSviewer Manual. Accessed on 25 July from https://www.vosviewer.com/documentation/Manual_VOSviewer_1.6.15.pdf.
Van Eck, N.J., Waltman, L., 2014. CitNetExplorer: A new software tool for analyzing and visualizing citation networks. J. Informetrics 8 (4), 802–823. https://doi.org/10.1016/j.joi.2014.07.006.
Van Eck, N.J., Waltman, L., Glänzel, W., 2017. Citation-based clustering of publications using CitNetExplorer and VOSviewer. Scientometrics 111 (2), 1053–1070. https://doi.org/10.1007/s11192-017-2300-7.
Vieira, E.S., Gomes, J.A.N.F., 2009. A comparison of Scopus and Web of Science for a typical university. Scientometrics 81 (2), 587–600. https://doi.org/10.1007/s11192-009-2178-0.

Vosviewer, 2021. Welcome to VOSviewer. Accessed on 27 July 2021 from https://www.vosviewer.com/.

Williams, J., Fugar, F., Adinyira, E., 2020. Assessment of health and safety culture maturity in the construction industry in developing economies: A case of Ghanaian construction industry. J. Eng., Des. Technol. 18 (4), 865–881. https://doi.org/10.1108/JEDT-06-2019-0151.

Windapo, A., Oladapo, A., 2012. Determinants of Construction Firms' Compliance with Health and Safety Regulations in South Africa. 28th Annual ARCOM Conference, Edinburgh, 3-5 September 2012, 433-444.

Worlddata, 2020. Developing Countries. Accessed on 26th July 2021 from https://www.worlddata.info/developing-countries.php.

Yang, S., Rui, D., Wang, H., 2020. A novel approach for occupational health and safety and environment risk assessment for nuclear power plant construction project. J. Cleaner Prod. 258, 120945 https://doi.org/10.1016/j.jclepro.2020.120945.

Zhao, X., 2017. A scientometric review of global BIM research, Analysis and visualization. Autom. Constr. 80, 37–47.