Bibliometric Analysis of Behavior-based Safety (BBS): Three Decades Publication Trends

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Abstract

Behavior-based safety (BBS) has flourished worldwide, with previous researchers extensively verified and provided scientific evidence that BBS was effective for managing risks and preventing injuries. This study aims to examine the bibliometric analysis of BBS publication patterns, research growth, and related publication information. A total of 333 BBS publications from the Scopus database were analyzed from 1989 to 2020. Data were exported to Microsoft Excel, Publish or Perish (PoP), and VOSviewer. This study evaluated data on the global trend of publication, contributions of countries, the encouragement of sources, leading authors, leading institutions, reference analysis, and keywords related to BBS research. Based on bibliometric parameters, this study found inconsistent publication trends in the last three decades. The results showed that BBS publications mainly fixated on engineering and medicine. The influential publication countries were the United States, China, the United Kingdom, and Australia. Safety Science was the most potent and compelling source. Academicians and professional authors actively engaged in writing BBS articles over three decades. Authors' keywords of "behavior-based safety", "safety culture", "accident prevention", "safety", and "organizational behavior management" has substantially impacted the online search for information. This research creates a new paradigm for comprehensive BBS study and intervention to improve future safety performance.

Keywords

Managing Risk, Influential Countries, Leading Authors, VOSviewer, Publish or Perish (PoP).

Introduction

Interventions focusing on Behavioral-based Safety (BBS) have flourished extensively, where previous researchers have thoroughly verified that implementation of BBS has successfully minimized risks and prevent injuries in a wide range of industries. Among the industries that implemented BBS were furniture industry (Niciejewska & Obrecht, 2020), food services industry (Lebbon, Sigurdsson & Austin, 2012), the construction industry (Li et al., 2015), and the pinewood processing plant (Jerie & Baldwin, 2017).

BBS is a safety intervention to minimize workplace injuries by observing, communicating, tracking, and promoting safe behavior. Talabi, Gibb, and Edum-Fotwe (2015) and Wang, Xing, Luo, and Yu (2018) argued that the success of BBS as a safety intervention required a strong positive safety culture with stable and systematic safety management. This belief forms a basis for developing safety theories over the last decades.

BBS, according to Watson (1924), is the science of observable behavior. Behaviourism principles include behavioral therapy, operant psychology, and applied behavioral analysis (DeJoy, 2005). According to Guo, Goh, and Wong (2018), BBS has gained substantial attention due to its effectiveness in preventing accidents since 1970s. However, researchers have different views on the definition of BBS (Wirth & Sigurdsson, 2008), but many noted its use as a catch-all word for safety measures focusing on the behavior of front liners.

The origins of BBS can be traced back to the classic Domino Theory (Heinrich, 1931), who said unsafe behavior and unsafe working environments are the root causes of injuries. Heinrich (1931) stated that 88% of the direct causes of injury were due to unsafe behavior, 10% were due to unsafe conditions, and 2% were unpreventable causes. Therefore, implementing BBS is necessary because workers' behavior can be influenced to affect their health and safety (Guo et al., 2018), which subsequently improves safety performance (Abdullah & Aziz, 2020b; Zhang, Chen & Sun, 2019). This bibliometric analysis is crucial for researchers to understand and evaluate the research status on BBS.

Bibliometric is a method that provides a convenient and non-reactive tool for research collaboration and assessment of scientific publications (Subramanyam, 1983).

Comprehensive bibliometric research has begun in various sub-domains of occupational safety and health such as safety climate (Bamel, Pandey, & Gupta, 2020), safety culture (Van Nunen et al., 2018), safety knowledge (Abdullah & Abd Aziz, 2020a), and process safety and risk analysis (Amin, Khan, & Amyotte, 2019). However, the bibliometric analysis of BBS is less studied by previous researchers. For that reason, this bibliometric analysis of BBS provides a macroscopic overview of research developments.

The source of the BBS intervention approach is from publications in high-quality journals, i.e., Scopus database. According to Weale, Bailey, and Lear (2004), the widely cited articles will most certainly have an impact and meaning on the research field. Thus, the bibliometric analysis reflected the essence of the work and considered suitable for evaluating research patterns and innovations (Ellegaard & Wallin, 2015).

This study aims to learn from the bibliometric analysis of BBS from the angle of (i) global trend of publications, (ii) contribution of countries, (iii) contribution of sources, (iv) leading authors, (v) leading institutions, (vi) reference analysis and (vii) analysis of keywords. The information provided in this study is expected to deliver a clear overview of BBS research direction that could enable readers, occupational safety and health professionals, and researchers to gain the information that benefits their studies. The approach to this bibliometric analysis could create significant contributions to existing BBS research.

Materials and Methods

The number of publications in any study area contributed to influential arguments for scholars to obtain relevant data. Thus, bibliometric analysis became a common research trend. In the past, the bibliometric analysis was a useful mathematical and statistical method to analyze books and other mediums of communication (Pritchard, 1969). Currently, bibliometric analysis is used to obtain information on publishing patterns, assess the quantity and content of publications, and analyze author details, keyword frequencies, and citations.

The bibliometric review was conducted using the VOSviewer software developed by Van Eck and Waltman (2010). According to Van Eck and Waltman (2010; 2019), VOSviewer applied visual elements based on mapping techniques, which converts data related to Comma Separated Values (CSV) format into diagrams or clusters. Also, mapping techniques help analyze data about authors, locations, institutions, citations, co-citations, and other refining aspects.

In this study, a bibliometric analysis was retrieved using the Scopus search engine on October 10, 2020. The Scopus database was selected because it has extensive documents compared to the Web of Science and Pubmed and has also been frequently cited in previous studies (Sweileh, 2020). The retrieved data was initiated with the identification of precise keywords, appropriate information, and the specific objective of the analysis. The keyword "Behavior-based Safety" based on TITLE-ABS-KEY was used to collect data on BBS publications. The quotation marks were used to produce accurate search results.

The result of retrieved data produces 333 publications from 1989 to 2020. Out of the 333 publications, 152 were articles from various journal sources, 143 were conference papers, 12 were review papers, and less than ten other publications such as notes, books, and short surveys. A total of 323 publications were written in English, eight in Italian, two in Chinese, and one in Spanish. Data in CSV and Research Information Systems (RIS) format such as years, authors, the field of study, article sources, countries, and languages were exported to Microsoft Excel, Publish or Perish (PoP), and VOSviewer software for further analysis.

Results

The Global Trend of Publications

The number of publications is an essential element for developing any research field. Figure 1 indicates the number of BBS publications from 1989 to 2020. The number of publications was stagnant between 1989 and 1995. There was only one paper per year and had been slackened off during the phase. The reason was that BBS studies' advancement was still at an earlier stage, and most scholars were new to BBS intervention. The number of publications fluctuated between 1996 and 2020. However, the number of publications rose steadily to more than five post-1998 publications. In 2010, 26 BBS publications were successfully published and recorded as the prime number in the last three decades.

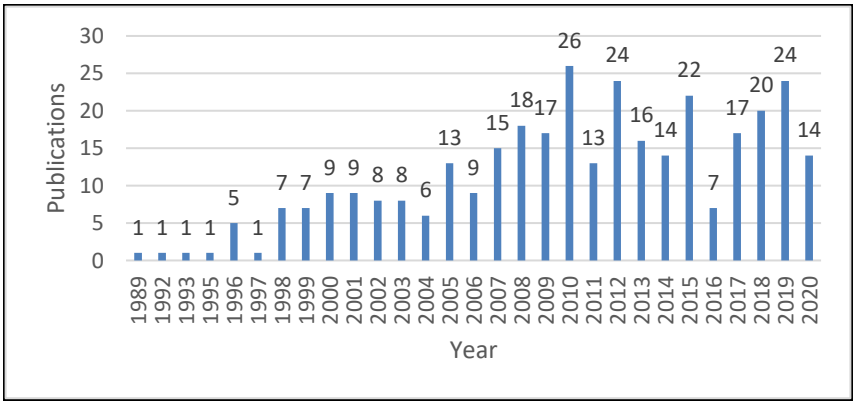

Figure 1 Research trend on BBS

Figure 2 shows the top five research hotspots on BBS. It showed that engineering ranked first in BBS with 203 publications, followed by medicine with 76 publications and Social Science with 66 publications. For the last 31 years, engineering has produced more than 200 BBS publications. This was because the nature of hazards in industries involving engineering activities and the man-hours exposed had made BBS implementation was necessary to manage risks and prevent injuries.

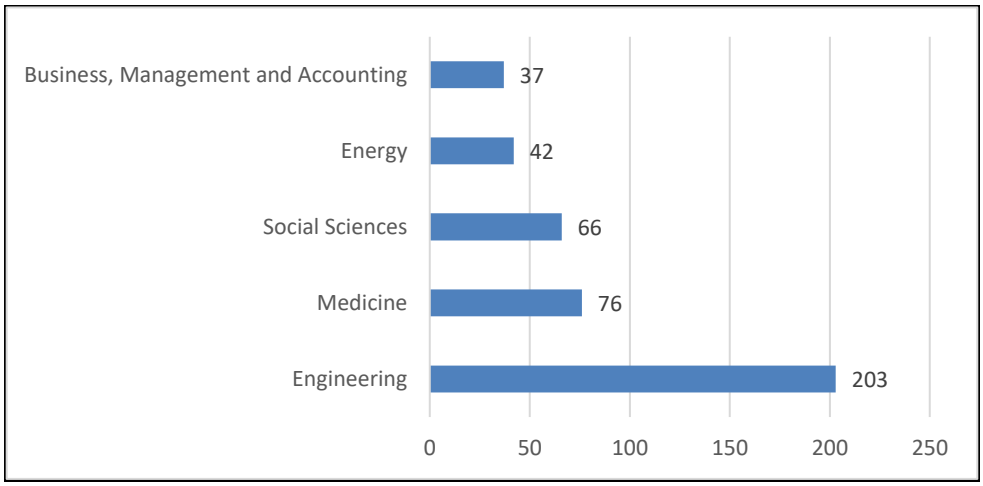

Figure 2 Research hotspot on BBS

Contribution of Countries

Scholars from 17 different countries have contributed to publishing BBS research with at least five documents, as depicted in Table 1. The top five on the list are the United States with a total of 114 publications (30.65%), followed by China (43 publications, 11.56%), the United Kingdom (18 publications, 4.84%), Australia (17 publications, 4.57%) and Malaysia (12 publications, 3.23%). Results indicate that developed countries have dominated the publishing of BBS for over 31 years. This was due to safety consciousness among employees in developed countries higher than employees in developing countries.

A map of the top-ranked countries is present in Figure 3. The size of the node indicates the number of publications. As shown in the map, the United States, China, the United Kingdom, and Australia were the world's top countries in publishing BBS articles. Lines connecting the countries indicated co-authorship. When the two countries related to each other by one line, they collaborated on the article's publication. The thickness of the line represented a high level of cooperation between countries. As shown on the map, there was scientific cooperation between China and most countries. China had the most scientific collaboration with Australia, Hong Kong, Taiwan, and Poland.

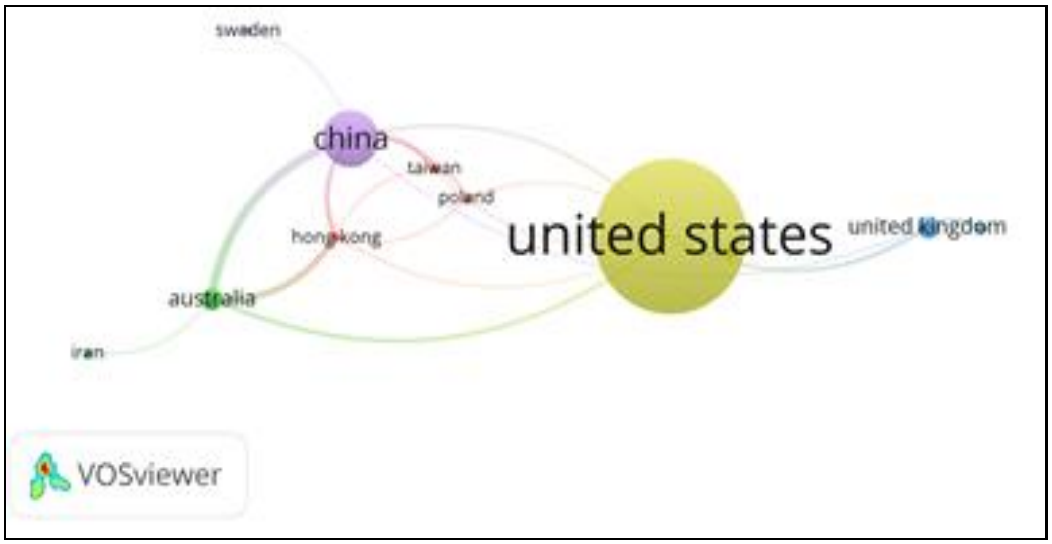

Figure 3 The co-authorship map of the top countries publishing BBS

Table 1 Status of top countries in the field of BBS

Rank	Country/Territory	Articles	Percentage (%)
1	United States	114	30.65
2	China	43	11.56
3	United Kingdom	18	4.84
4	Australia	17	4.57
5	Malaysia	12	3.23
6	India	11	2.96
7	Italy	9	2.42
8	Indonesia	8	2.15
9	Iran	7	1.88
10	Hong Kong	6	1.61
11	Kuwait	6	1.61
12	Sweden	6	1.61
13	Germany	5	1.34
14	Japan	5	1.34
15	Poland	5	1.34
16	South Africa	5	1.34
17	Taiwan	5	1.34

Contribution of Sources

Figure 4 shows the map of influential sources on BBS publications. According to visualization results, the most important source was the Safety Science. The primary sources of publishing BBS publications were located in three clusters (red, green, and blue). The red cluster contained sources, such as ASSE Professional Development Conference and Exposition 2000, Giornale Italiano Di Medicina Del Lavoro Ed Ergonomia, Occupational Health and Safety, and Safety Science. The green cluster included Advances in Intelligent Systems and Computing, Journal of Organizational Behavior Management, and Journal of Safety Research. The blue cluster consisted of two sources; Automation in Construction and Journal of Construction Engineering and Management.

More than 294 sources were cited in BBS publications. Among all references cited, Automation in Construction, Ergonomic, and Safety Science were the essential sources. Figure 5 shows the co-citation map of the top sources cited in BBS. This map was composed of red, green, and blue clusters. The first red cluster included Accident Analysis and Prevention, Journal of Safety Research and Safety Science. The blue cluster contained sources such as the Journal of Organizational Behavior and Professional Safety. The green cluster belonged to Automation in Construction, Journal of Applied Psychology, Journal of Computing in Civil Engineering, and Journal of Construction Engineering and Management.

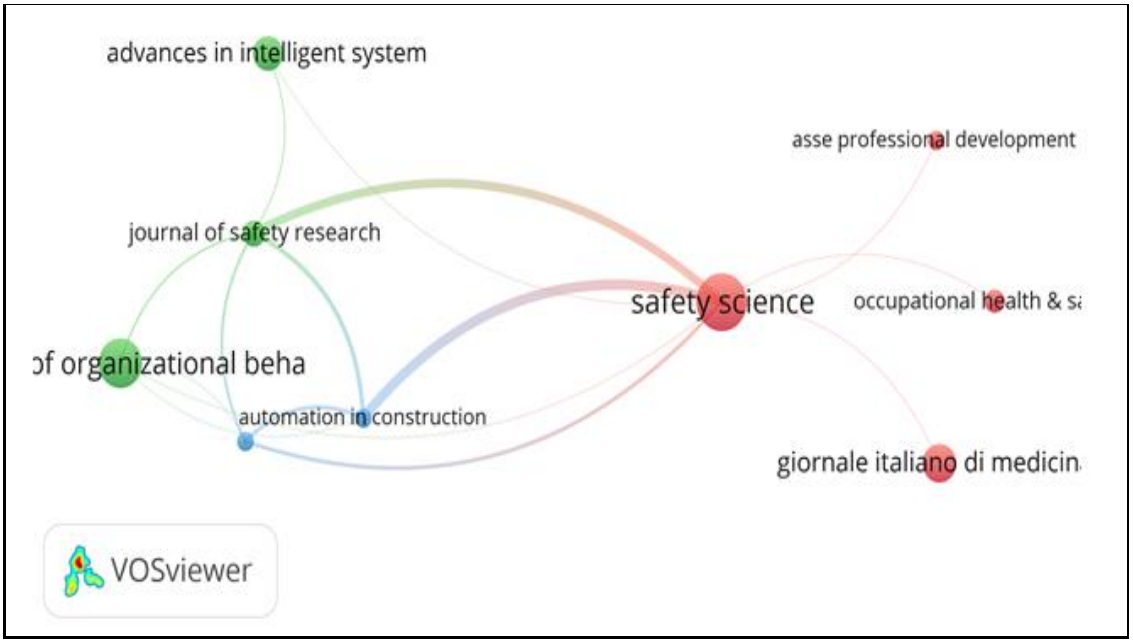

Figure 4 Map of influential sources on BBS publications

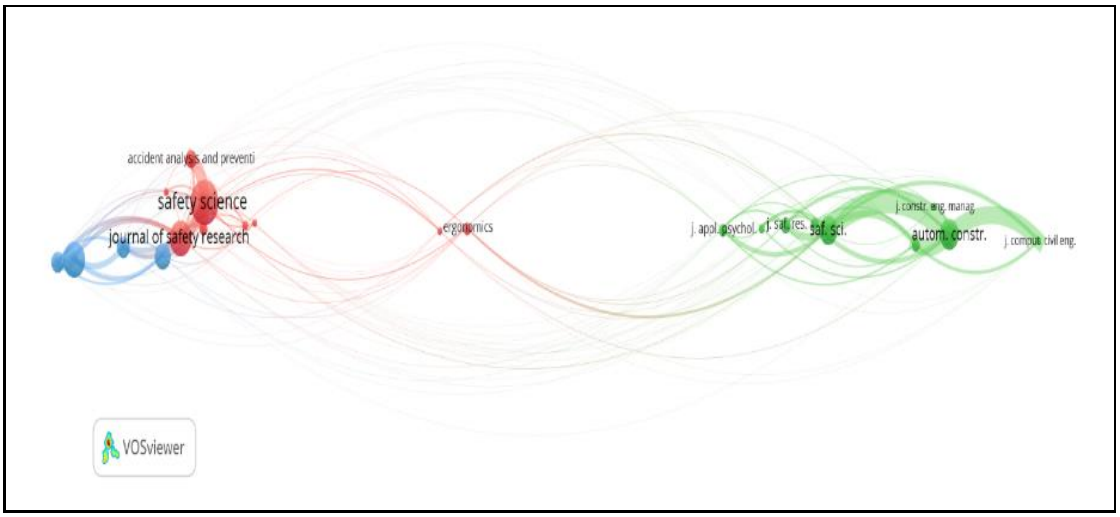

Figure 5 The Co-citations map of sources cited in BBS

Leading Authors

Table 2 indicates six authors who have published more than five publications on BBS over the last 31 years (1989-2020). The information was based on the number of articles, H-index, affiliation, and country. Based on leading authors, Austin, J. affiliated to the Reaching Results, Kalamazoo, U.S., was ranked first with nine articles and an H-index of 18. Galloway, S.M., from the ProAct Safety, U.S., and Geller, E.S., from the Virginia Polytechnic Institute and State University, U.S., was ranked second with eight articles. Fand, D. from the Tsinghua University, China, and Kaila, H.L., from the Shreemati Nathibai Damodar Thackersey Women's University, India, were rank third with six articles. Finally, Krause, T.R., of the RAND Corporation, U.S., was ranked fourth.

Leading Institutions

In total, 160 universities, institutes, and research centers participated in publishing BBS publications. Figure 6 shows the information about the institution that publishes at least five publications on BBS. The most leading institution with nine publications was credited to the researchers at Tsinghua University. The Virginia Polytechnic Institute and State University were ranked second with eight publications. The third rank was shared by Western Michigan University and Los Alamos National Laboratory with seven publications. As far as the top five institutions are concerned, a fascinating fact is that three of them belong to the United States and two to China. Such findings have shown that the United States and China have been the leading countries in publishing scientific documents worldwide. Another significant result is that the Los Alamos National Laboratory under the U.S. Department of Energy was the top research center for publishing BBS publications.

Table 2 Status of top authors in the field of BBS

Rank	Author	Articles	H-index	Affiliation	Country
1	Austin, J.	9	18	Reaching Results, Kalamazoo	United States
2	Galloway, S.M.	8	1	ProAct Safety	United States
2	Geller, E.S.	8	34	Virginia Polytechnic Institute and State University	United States
3	Fang, D.	6	30	Tsinghua University	China
3	Kaila, H.L.	6	3	Shreemati Nathibai Damodar Thackersey Women's University	India
4	Krause, T.R.	5	2	RAND Corporation	United States

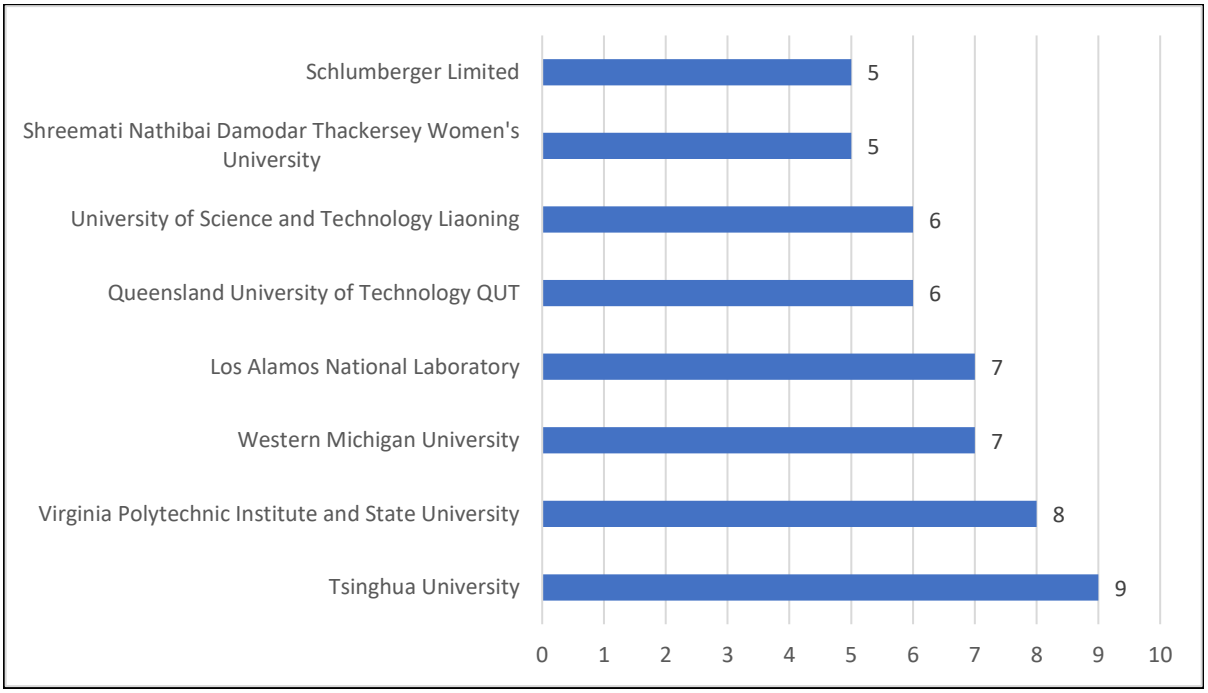

Figure 6 Top universities and institutes publishing articles on BBS

Reference Analysis

Reference analysis is one of the primary bibliometric identification processes. Table 3 recapitulates the citation metrics for BBS publications. As noted, there were 3195 citations published in the 31 years of BBS. Citation metric was obtained via Publish or Perish (PoP) software by importing files in RIS format from the Scopus database.

Table 3 Metrics citation

Metrics	Data
Publication years	1989 - 2020
Citation years	31 (1989 -2020)
Papers	333
Citations	3195
Citation / year	103.06
Citation / paper	9.59
Author / paper	2.41
Hirsch h-index	27
Egghe g-index	52
PoP hI, the norm	20
PoP hI, annual	0.65

To identify the highly-cited papers in the field of BBS, we examined the top documents with the most citations. Table 4 shows the top ten most cited articles (based on the text's citation number) as per the Scopus database. Choudhry, Fang, and Mohamed (2007) published an article entitled "The nature of safety culture: A survey of the state-of-the-art" issued by the Safety Science obtained the highest number of citations (315 citations). Safety Science published four articles and was a leading publication of the top ten most frequently cited BBS.

Figure 7 shows the co-citations map of the top 20 authors. Co-citation analysis establishes similarities between scientific studies, publications, or authors. As the same pairs of articles are co-cited by several contributors, study clusters tend to form. Co-citation analysis is piloted to identify interconnections networks among BBS publications retrieved from the Scopus database by VOSviewer software. This article revealed that the authors were included in three clusters with green, red, and blue colors based on the analysis. The size of the nodes represented the most cited authors.

The green cluster consisted of the authors with high citations, namely, Geller, E.S., Austin, J., Sulzer-Azaroff, B., and Kakami, J. The red cluster included authors, such as Zohar, D., Cooper, M. D., Fang, D., and Rowlinson, S. The blue cluster had four authors, namely Teize, J., Li, H., Lee, S., and Han, S.

Table 4 Highly-cited articles on BBS

Ranks	Cites	Cites Per Year	Authors	Title	Source	Year
1	315	24.23	R.M. Choudhry, D. Fang, S. Mohamed	The nature of safety culture: A survey of the state-of-the-art	Safety Science	2007
2	291	24.25	M. Dağdeviren, I. Yüksel	Developing a fuzzy analytic hierarchy process (AHP) model for behavior-based safety management	Information Sciences	2008
3	155	22.14	S. Han, S. Lee	A vision-based motion capture and recognition framework for behavior-based safety management	Automation in Construction	2013
4	124	5.39	H. Lingard, S. Rowlinson	Behavior-Based Safety Management in Hong Kong's Construction Industry	Journal of Safety Research	1997
5	121	24.2	H. Li, M. Lu, S.-C. Hsu, M. Gray, T. Huang	Proactive behavior-based safety management for construction safety improvement	Safety Science	2015
6	112	5.33	J.P. Depasquale, E.S. Geller	Critical Success Factors for Behavior-Based Safety: A Study of Twenty Industry-wide Applications	Journal of Safety Research	1999
7	111	5.29	T.R. Krause, K.J. Seymour, K.C.M. Sloat	Long-term evaluation of a behavior-based method for improving safety performance: a meta-analysis of 73 interrupted time-series replications	Safety Science	1999
8	108	18	R.M. Choudhry	Behavior-based safety on construction sites: A case study	Accident Analysis and Prevention	2014
9	106	15.14	D. Fang, H. Wu	Development of a Safety Culture Interaction (SCI) model for construction projects	Safety Science	2013
10	105	21	D. Fang, C. Wu, H. Wu	Impact of the supervisor on worker safety behavior in construction projects	Journal of Management in Engineering	2015

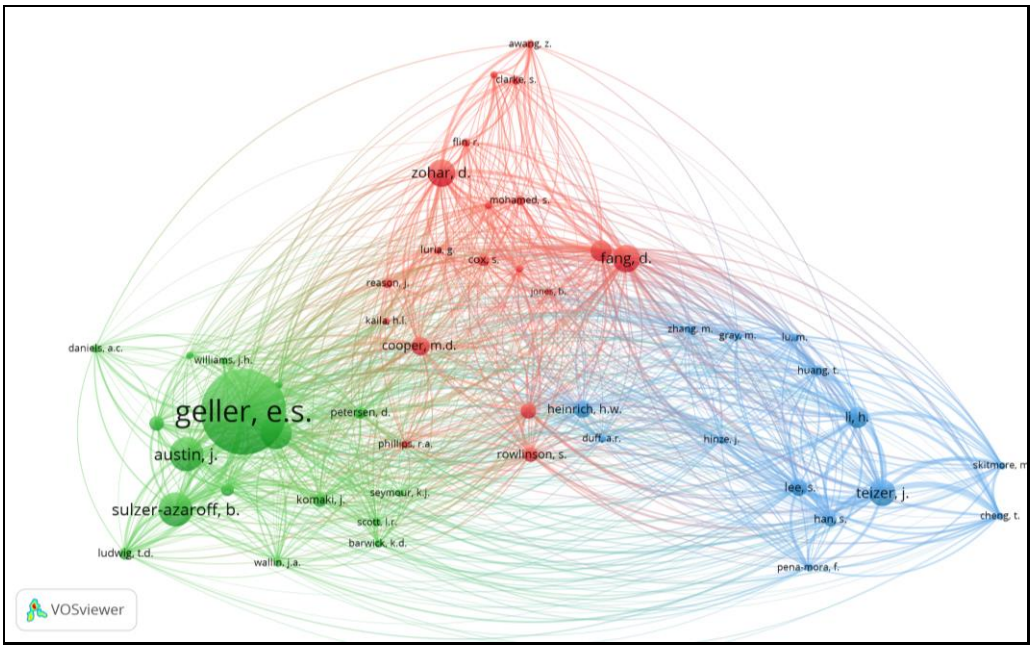

Figure 7 The Co-citations map of authors cited in BBS publications

Analysis of Keywords

Keywords aid to imitate research hotspots and help researchers to identify new frontier issues. By analyzing articles' common keywords, we realized the essence of the research focusses comprehensively. In this analysis, VOSviewer had mapped the keywords of the authors. Figure 8 provided a network diagram of the author's keywords in which color, node size, font size, and thickness of the connecting lines illustrated the relationship with other keywords.

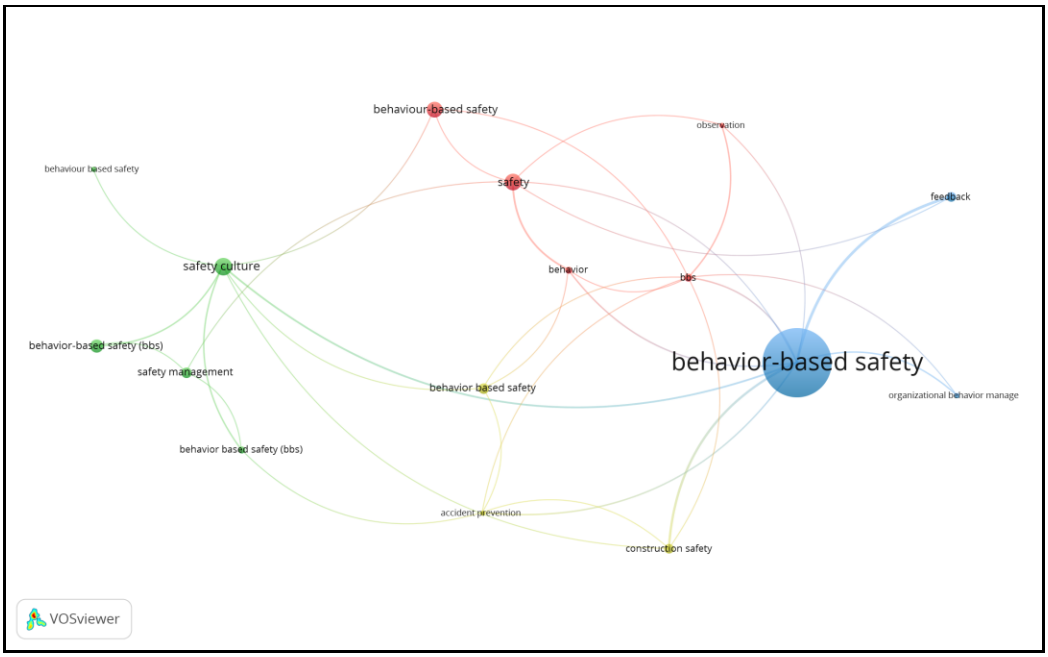

Figure 8 The co-occurrence map of the author's keywords

There were 4 clusters in Figure 8 to build a network with keywords of blue, green, red, and yellow nodes. Each cluster included BBS keywords with varying spelling and writing types, such as short-form and with or without dashes. The closeness in the distance between keywords indicates the higher the relationship between keywords. The distance between the keywords of "behavior-based safety", "safety culture", "accident prevention", "safety", and "organizational behavior management" is close and has a substantial impact.

This analysis also inspected the titles and abstracts of the retrieved documents based on the number of co-occurrences - the binary counting method was used to create a co-occurrence network by authors. Van Eck and Waltman (2019) claimed that using binary counting means the number of noun phrases appears in the title, and the abstract does not play a significant role and is equally concerned. Figure 8 demonstrated the co-occurrence network based on the title and abstract fields. The overall strength of the relationship between the terms was 8413. As shown in Figure 9, the map of the terms extracted consisted of four clusters. Accident, unsafe behavior, model, research, intervention, application, safety management, and change were the top terms in the articles' title.

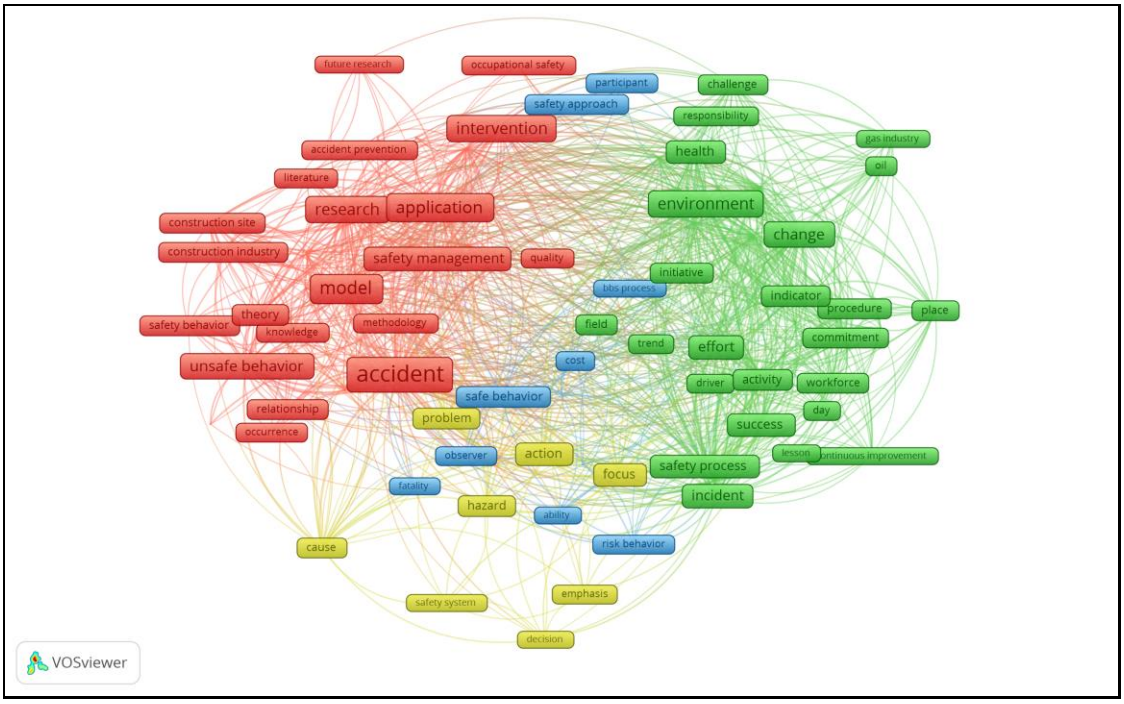

Figure 9 Network visualization map of a term of co-occurrence in abstract and title

Discussion and Conclusion

The present study shows that 333 BBS publications were indexed in the Scopus over the last three decades. The findings also revealed fluctuation in publishing patterns, with the

number of publications stagnated between 1989 and 1995. There was only one paper a year, and it had been slowed down during the phase; the number of publications has fluctuated between 1996 and 2020. There was a sharp rise in publications that occurred every five years since 2000. This finding could enable future researchers to systematically review the content of publications to recognize the themes for the trending of publications.

"Austin, J.", "Galloway, S.M.", "Geller, E.S.", "Fang, D.", "Kaila, H.L.", and "Krause, T.R." were the leading authors of the BBS publications. Most of the top authors belonged to the institutions of the United States. And it is exciting that this study reveals the most prominent authors come from professional organizations, i.e., Reaching Results in Kalamazoo and ProAct Safety. This information has shown that BBS research has gained professional researchers' attention and was further verified the discussion in an article published by Sulzer-Azaroff and Austin (2000).

The United States was a leading publishing country with 114 publications, followed by China, the United Kingdom, Australia, and Malaysia. China and Malaysia have been an Asian country that is actively publishing BBS research. China has been the second-most on the list and has come closer to the United States to be a productive country. This information could confirm an analysis published by Leydesdorff, Wagner, and Bornmann (2014) that China strengthened its top publications' proportions.

The analysis of universities, institutes, and scientific centers confirmed the superiority of the U.S. A fascinating fact is that three of them belong to the United States and two to China. Such findings have shown that the U.S. and China have been the leading countries in publishing scientific documents worldwide. According to the map of core journals and influential sources, Safety Science was the most critical journal. This journal is the most important in BBS research and is projected to publish more articles. Safety Science was based in the Netherlands and was categorized as a high-impact publisher by Scopus with First Quartile (Q1). This information will help readers and other researchers to get a good source of BBS publications.

Keyword analysis was one of the critical sections of this article. Keywords represent the fundamental concepts of the publications so that their visualization could deliver exciting results. "Behavior-based safety", "safety culture", "accident prevention", "safety", and "organizational behavior management" have a related and significant impact. This result was capable of creating a new paradigm for comprehensive BBS intervention in the future.

Finally, it is connoted that BBS publications in the last three decades could better understand BBS research's intellectual patterns and prevailing discourses that benefit future researchers. An auxiliary review may also concentrate on some of BBS research developments considered from a specific scientific perspective. VOSviewer software also endorsed further research, using more mapping or bibliographical methods, or other methodologies or software that might enrich this study, using other feasible bibliographic works.

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