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Visualized analysis of safety climate research: A bibliometric data mining approach

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ABSTRACT

It is well known that safety climate (SC) has paramount significance in safety science and accident prevention. In this paper, a bibliometric data mining is conducted to systematically review the research domain of SC. Overall, 1624 documents on SC are obtained, covering 4830 authors, 473 journals, 89 countries/regions, and 1766 institutions between 1980 and 2021. SC has obtained increasing attention since the number of publications related to SC grew from 1 in 1980 to 188 in 2020. Based on the bibliometric data, network analysis was carried out to understand the relationship among different countries/regions, authors, and keywords. Safety Science, Journal of Safety Research, and Accident Analysis and Prevention are the major sources of SC publications, and the USA, Australia, and China lead scientific collaboration production on SC research. Then, text mining of publication keywords is used to identify the hot topics and the evolution of mainstream research over time in the SC domain. The dominant topics in SC research include culture, performance, safety behavior, and model. Meanwhile, the limitations of past research on SC are analyzed and the differences between SC and safety culture are discussed. Moreover, recommendations for future research on SC are also given based on the results of bibliometric analysis and existing literature reviews.

1. Introduction

Nowadays, safety issues obtain increasing attention due to the increasingly complex technology and the rapid development of industrialization and urbanization (Yang, 2012). Accidents pose a threat to human lives and social development in terms of injuries, fatalities, and economic losses (Wang et al., 2018). Therefore, it is essential to locate effective solutions in daily safety management. In general, occupational health and safety performances can be attributed to multiple causes (Kvalheim and Dahl, 2016; Guo et al., 2016), including organizational, behavioral, and technical factors. According to the Swiss Cheese Model (Reason, 1997), organizational factors play an important role in shaping human safety behavior (Guo et al., 2016). Organizational SC is considered as "how the employees perceive the organization's approach towards safety" (Zarei et al., 2016). Zohar (1980) presented SC as a tackle to describe workers' views of the safety value and role in the organizations. SC refers to employees' common views on environmental safety management in their work (Hahn and Murphy, 2008). It serves as a measurable aspect (marker) or a surface manifestation of safety culture in an organization (Hahn and Murphy, 2008; Huang et al., 2013; Murphy et al., 2018; Reniers et al., 2011). Additionally, SC can be considered as both a leading and a lagging indicator of safety events (i.e., accidents, injuries). When SC is seen as a lagging indicator, SC data are interrelated with prior safety events (Payne et al., 2009). In this socio-technical age, SC is seen as an important means of accident prevention (Shen et al., 2015). Many studies demonstrate the benefits of creating a positive SC in workplaces. Pandit et al. (2019) revealed that workers representing a workplace with a more positive safety climate with a higher level of hazard identification and safety risk perception. SC can contribute to a great change in employees' behavior and mind, obtaining genuine safety

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implementation and decreasing accident rates (Kim et al., 2019). Newaz et al. (2019) argued the fact that SC affects safety behavior and promotes better safety effects in construction. Most researchers (Pandit et al., 2019) indicated that a direct correlation exists between safety climate and appropriate behaviors (utilization of individual protective supplies, adherence to safety regulations, and sharing safety knowledge). Also, safety climate was confirmed to be related to safety performance and attitudes (Kouabenan et al., 2015). Silva et al. (2004) designed OSCI (Organisational and Safety Climate Inventory), to address the characterization of both organizational climate and SC. In general, safety climate has been regarded as a basic method for promoting workplace safety in all types of industries (Ma and Yuan, 2009).

Since increasing people realize the necessity of institutional elements in safe work, a lot of SC studies were executed in different fields, covering construction (Newaz et al., 2019), manufacturing (Liu et al., 2015; Ma and Yuan, 2009), oil and gas (Kvalheim and Dahl, 2016), transportation (Amponsah-Tawiah and Mensah, 2016; Xu et al., 2018), nuclear facilities (Kasim et al., 2019), and airlines (Ji et al., 2019). Meanwhile, some studies on different kinds of SC appeared in recent years, such as organizational safety climate (Russell et al., 2022), nurses' safety climate (Memarbashi et al., 2021), and psychosocial safety climate (Dollard et al., 2012; Dollard,2022). Besides, relevant studies of SC are global and encompass Western and Eastern cultures (Murphy et al., 2014).

The first publication on SC appeared in 1980 (Zohar, 1980), and then much attention has been paid to this field referring to its definition and measurement. Cooper et al. (2004) summarized four topics in SC research, including designing measurement instruments, developing theoretical models, examining the relation with safety performance, and revealing the links to organizational climate. Zohar (2010) pointed out that a lot of work about safety climate mainly concentrates on methodologies instead of theoretical and conceptual issues by looking back over 30 years of relevant research in this field. There are more than forty different tools to test safety climate, with questionnaires as the most utilized methodology (O'Connor et al., 2011). Liu et al. (2015) reviewed the constructs applied to evaluate SC, focusing on management commitment, supervisor and co-worker support, safety awareness, safety policy, safety knowledge, safety education, etc.

Several existing review-based studies on SC such as Bamel et al. (2020), Lee et al. (2019), Li et al. (2021), and Shea et al. (2021) were not free from limitations. Bamel et al. (2020) applied structured network analysis, but did not provide any sentiment analysis of cited works and did not tell us the times a publication was cited in a paper. Lee et al. (2019) aimed to examine trends in SC interventions and provide a compilation of information for the design and implementation of evidence-based SC interventions. Shea et al. (2021) only examined the psychometric properties of each measure of SC as reported in its original publication.

The existing papers usually do not give the entire picture of SC research, which motivates the use of bibliometrics. A literature review is an effective method to achieve a specific field in a relatively short time. Although *meta*-analysis combines clear rules to find and study comprehensive data statistics (Alruqi et al., 2018), this approach is less subjective and does not remove subjectivity from the analysis process (Sigman, 2011). Bibliometrics is a citation visualization analysis method developed based on scientometrics and data visualization, which has a good analysis and prediction of the research status and development trend on knowledge mapping.

As an effective tool for mapping documents of disciplines, bibliometrics can quantify collaborations, co-citation, research topics, and research trends in a research field. It refers to a method of research applied in library and information sciences that uses statistical and quantitative analysis to characterize dissertations on a particular topic, field, institution, or country. These methods have been applied to research trends in a specific field (Ho, 2008; Li et al., 2009). As a quantitative analysis technique, bibliometric methods are deployed to identify the state and gaps in a field (Chen et al., 2016; Pan et al., 2018; Taddeo et al., 2019; Yang et al., 2019; Zou et al., 2018). There are many examples of bibliometrics studies in the literature based on different topics such as transportation research (Sun and Rahwan, 2017), construction safety research (Jin et al., 2019), safety and security research (Gou et al., 2022), greening ports and maritime logistics (Davarzani et al., 2016), automotive industry supply chains (González-Benito et al., 2013), smart factory (Strozzi et al., 2017), entrepreneurship (Landström et al., 2012). Additionally, bibliometric tools have been widely employed various of environmental and ecological fields, including digital learning environments (Schbel et al., 2021), human and environment (Catharina et al., 2021), behavioral ecology (Quinn et al., 2019), and area ecological research (Liu et al., 2021). The relevant results have practical significance for experts and scholars to explore the exemption of future research content and excavate deeper cooperation with other teams.

This paper uses a bibliometric approach to review research in SC and understand the field based on records extracted from the Web of Science (WoS) Core Collection. The purpose of this paper is to summarize the basic characteristics of SC publishing from a macro perspective, and to make a clear description of the development process of SC research. The annual output, geographical distribution, leading journals, overall situation in terms of collaborative networks, citations, hotspots and research trends are generally accepted. Section 2 refers to data sources, analysis software, and methods of bibliometric. Section 3 presents the results of the analysis. Sections 4 and 5 illustrates the discussion and conclusions respectively.

2. Methodology

2.1. Data source

The data and information used in this scientific research were obtained from the Core Collection database of WoS. The search was completed on October 30, 2021. WoS database is a scientific and reasonable database for publishing and distributing research which is widely used by academics around the world (van Nunen et al., 2018; Yang et al., 2013). To obtain the research related to SC in the database, the term "safety climate" was set as the search topic. Since the first paper on safety climate was published in 1980 (Zohar, 1980), the timespan was set from 1980 to 2021. Not all the retrieved documents were actually related to SC, due to the other meaning of safety climate. Therefore, based on the information provided by the summary and the text, an artificial screening was performed to exclude results relevant to the topic. Besides, all categories of documents in WoS were included in this search. Most of them were the content and evaluation of scientific research articles. Other file attributes, such as conference abstracts, conference papers, preparation materials, and the total number of book chapters were relatively limited (all less than forty). The publication and distribution of each chapter in WoS included a lot of detailed information. Finally, a total of 1,624 documents related to safety climate were retrieved. The full records is then output, containing citations to the 1,624 selected documents for bibliometric analysis.

2.2. Bibliometric analysis

VOSviewer is a bibliometrics software based on data mining, which guides the sample literature data to VOSviewer and draws the knowledge map. It possesses the ability to demonstrate the general characteristics of this field, with the unique advantages of cluster analysis (Yang et al.,2019; Tao et al., 2020a). Bibexcel can only construct a social relationship matrix, not network clustering data, and the operational steps are extremely complex (Zhou, 2017). Citespace can not be used to distinguish the form of cases, singular or plural in English data. The problem of overlapping node labels occurs when a clustered network is formed (Markscheff and Schroeter, 2021). Compared with Citespace and

Bibexcel, the advantage of VOSviewer is to visualize the knowledge units of the literature and has a strong graphics presentation ability (Chen et al., 2021). This makes it suitable for analyzing large sample data (van Eck and Waltman, 2010; Zhou, 2017). Moreover, it includes 4 browsing forms: density views, cluster views, label views, and decentralized views. This scientific research selected the open-access software VOSviewer for analyzing the obtained literature records between 1980 and 2021 and exploring its research hotpot and development trend. The research procedure and method used are shown in Fig. 1.

The graph theory clustering method based on VOSviewer is used to divide the theme style into different groups, in which each cluster uses a different color tone (Tao et al., 2020b). Part of the results expresses big data visualization.

3. Results

3.1. The growth and output of publication

The number of publications can reflect the development trend of a specific research field over time (Yang et al., 2019). Using the research topic of "safety climate", a total of 1,624 publications were found. As shown in Table 1, it can be seen that 9 document attributes exist in publishing. There are 1493 Journal articles. They are followed by reviews, conference abstracts, and proceeding papers. It can be inferred that conferences can provide an important platform for conducting and communicating SC research. The remainder less than 1 % includes editorial materials, book chapters, corrections, letters, and news items.

The yearly number of publications and cumulative number of SC is described in Fig. 2. In general, the number of SC papers has rapidly increased from one in 1980 to 188 in 2020, which shows that the importance and attention of SC are constantly increasing. Since 2005, the number of papers has been rising steadily, but in 2006, 2011, and 2014, there was a clear downward trend. In 2010, the first notable increase (n = 72) of publications appeared due to a special issue in the journal of *Accident Analysis and Prevention* on SC (Huang et al., 2010). In 2020, a peak of SC publications was reached (n = 188). Meanwhile, the total number of safety climate-related publications increased exponentially, which is consistent with the development of corporate safety culture scientific research references. Additionally, the cumulative number of papers published shows a linear upward trend, which is positively correlated with the number of publications of the six core safety journals (Li and Hale, 2016). Such things may be due to the understanding of the necessity of institutional elements in safety work, and the contribution of many experts and scholars to SC research. However, compared with the documents in other sub-domains of safety (such as safety culture, university laboratory safety, and road safety) (Jin et al., 2019; Yang et al., 2019; van Nunen et al.,2018), SC is still in the under-researched stage, suggesting that there is much room for development.

3.2. Geographical distribution of publications

In this section, SC publications were analyzed by authors' addresses and affiliations to find out the allocation of publications by countries/regions and institutions. The results show that the academic documents that we retrieved on SC come from 89 countries/regions. To better clarify the essential countries/regions participating in SC research and the collaboration among them, the top 20 country/region references are shown in Fig. 3. The top 20 countries/regions account for more than 85 % of the number of publications. The United Kingdom (569, 35.0 %) ranked No.1 with the largest total number of periodicals in all countries, additionally followed by Australia (215, 13.2 %), China (137, 8.4 %), England (115, 7.1 %), Canada (77, 4.7 %). Similarly, the United Kingdom ranks first in a single domestic and international exchange publication and its first author and corresponding author's publication and distribution level.

Collaborative relationships between countries/regions were also surveyed. Additionally, clusters of cooperation are indicated by different colors. As depicted in Fig. 4, the publications are completed by cooperation for most countries and regions. For example, the USA intensively cooperates with Canada, England, and Israel, while China has relationships with Australia. Moreover, it can be found that a major geographical clustering of countries/regions cooperation exists, e.g. North American countries comprising the USA and Canada; the Pacific countries/regions covering Australia, China, and Malaysia; Nordic countries comprising Norway, Scotland, and Sweden. In general, more cross-national cooperation in the SC field should be enhanced in the future.

Table 1
Number of SC documents in each category during 1980–2021.

Rank.	Type of document s	No. of documents	Percentage
1	Article	1439	88.6 %
2	Review	73	4.5 %
3	Proceeding paper	44	2.7 %
4	Meeting abstract	42	2.5 %
5	Editorial material	13	0.8 %
6	Correction	6	0.4 %
7	Book chapter	3	0.2 %
8	Letter	3	0.2 %
9	News item	1	0.1 %
Total	–	1624	100%

3.3. Source of publications

The publication source analysis is an useful approach of distinguishing core journals related to SC, and also provides an effective way for academia and researchers. The distribution of core journals in the SC domain can be recognized by journal analysis. According to statistics, a total of 473 academic journals were included from 1980 to 2021. Table 2 lists the rankings of active journals in which nearly 528 publications are published in these journals (32.5 % of all SC publications). As you can see, *Saf. Sci.* is the journal with the highest production, followed by the *J. Saf. Res.*, *Accid. Anal. Prev.*, *Int. J. Occup. Saf. Ergon.*, *BMC Health Serv. Res.*, *Int. J. Environ. Res. Public Health*, and *BMJ Quality Safety*. In terms of impact factor in 2020, *J. Appl. Psychol.* is the most

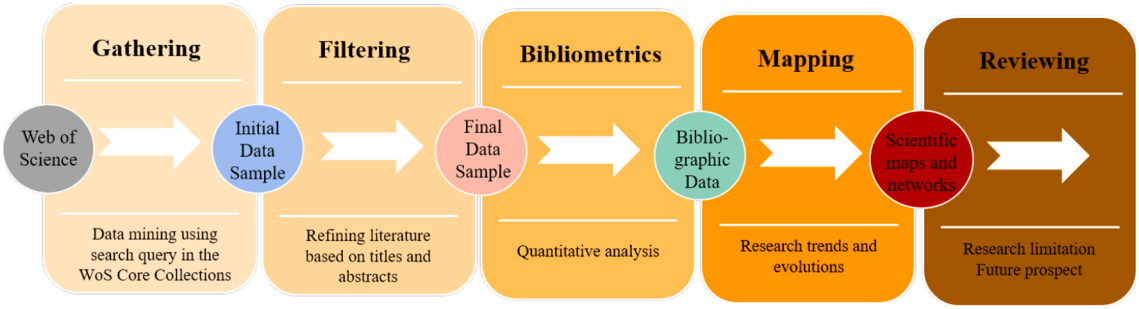

Fig. 1. The used research procedure and method.

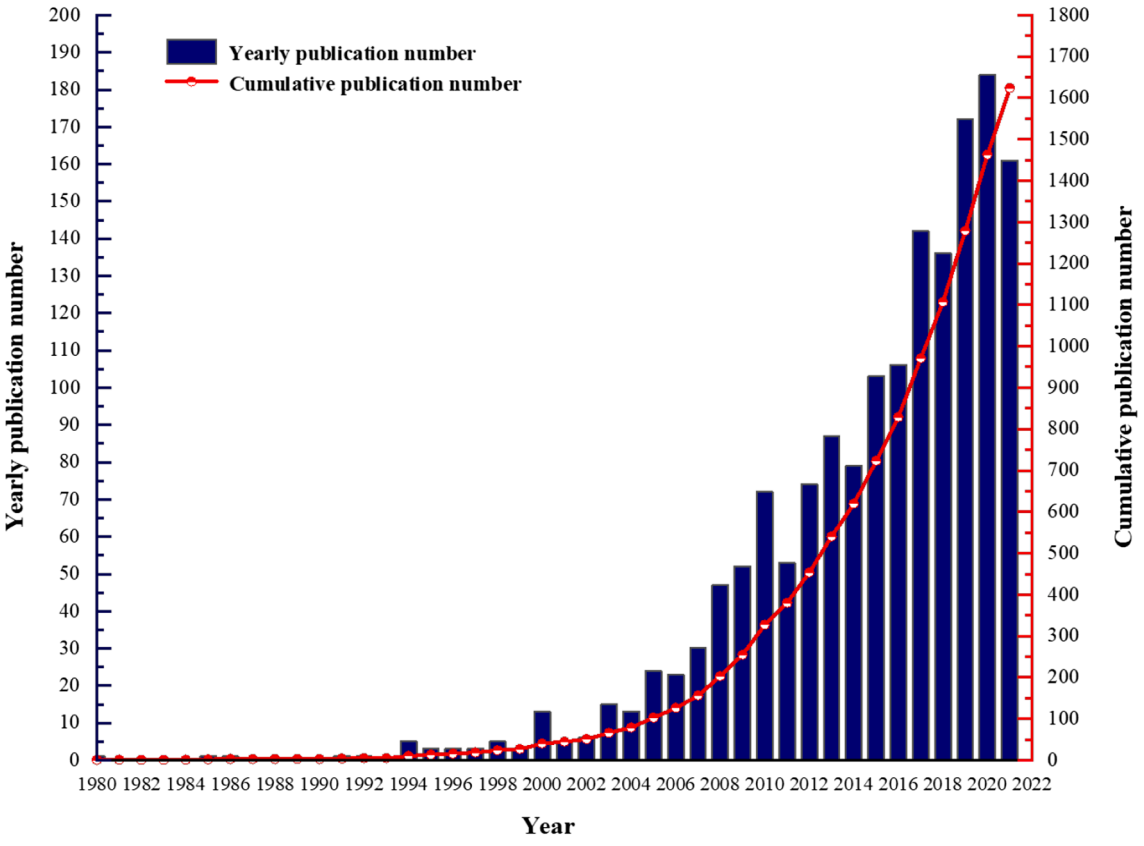

Fig. 2. The yearly publication number and cumulative number of SC.

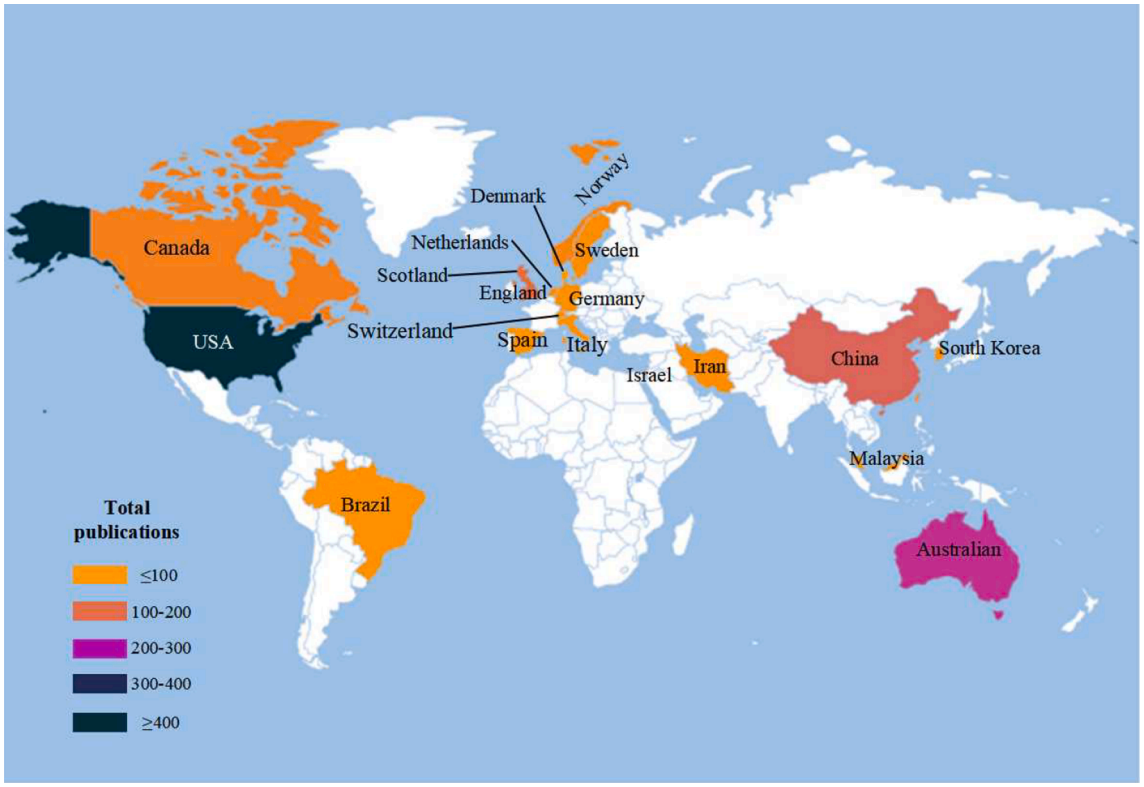

Fig. 3. The top 20 country/region distribution of the literature.

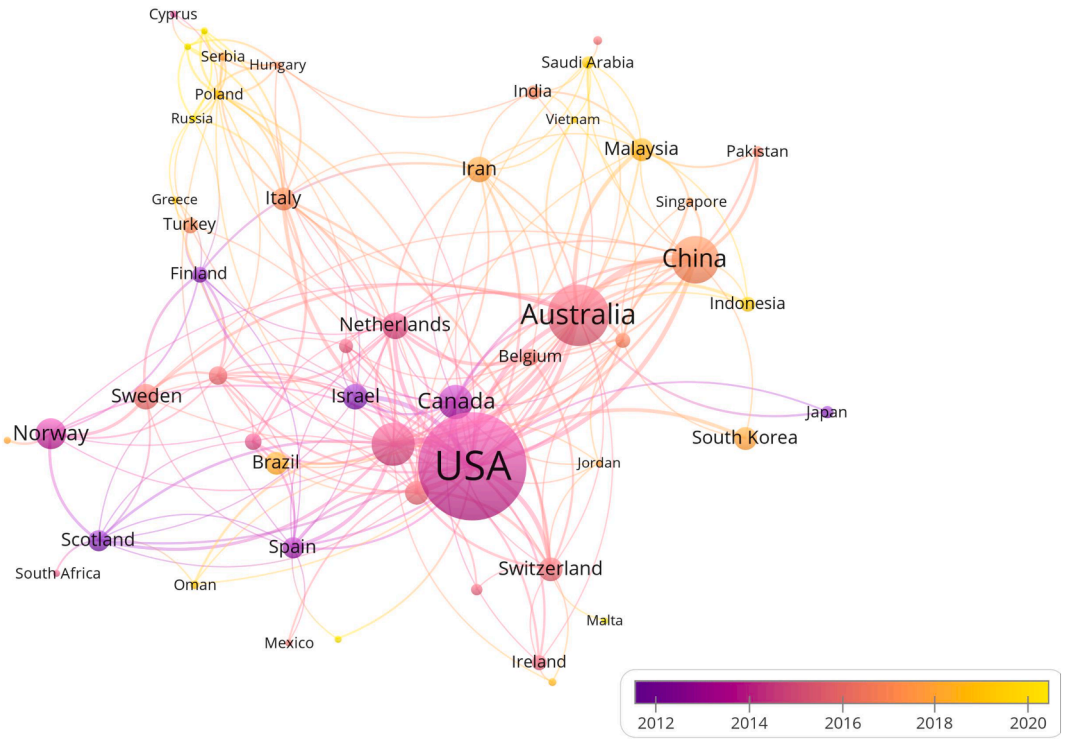

Fig. 4. Cooperation network relationship among countries or regions in fields of SC.

Table 2
The rank of active journals about publications of SC (Top 10).

Journal	No. of publications	Proportion (%)	Citations	Impact factors in 2020	Subject category
Saf. Sci.	174	10.7	6875	4.877	Engineering; Operation research & management science
J. Saf. Res.	72	4.4	2839	3.487	Ergonomics; Public, environment & occupational health
Accid. Anal. Prev.	65	4.0	2631	4.993	Ergonomics; Public, environment & occupational health
Int. J. Occup. Saf. Ergon.	41	2.5	210	2.141	Ergonomics, Public, environment & occupational health
BMC Health Serv. Res.	37	2.2	1108	2.655	Health care science & service
Int. J. Environ. Res. Public Health	34	2.1	151	3.390	Public Environmental & Occupational Health Environmental Sciences
BMJ Qual. Saf.	33	2.0	1068	7.035	Health care science & service
J. Appl. Psychol.	26	1.6	5332	7.429	Psychology, Business & economics
Am. J. Ind. Med.	23	1.4	309	2.214	Public, Environment & occupational health
Int. J. Qual. Health Care	23	1.4	378	2.038	Health care sciences & services

influential journal in SC studies, followed by *BMJ Quality Safety*, *Accid. Anal. Prev.*, *Saf. Sci.* Besides, the core journals in SC research are multidisciplinary including *Public, environment & occupational health, Health care sciences & services, Ergonomics, Psychology*, and *Engineering*, etc. At the same time, it also includes engineering, medicine, psychology, management and other disciplines.

3.4. Cooperation network analysis

1766 organizations from 89 countries and 4830 authors participated in the publication and distribution of 473 articles related to SC. To better explore different structures and scientific research collaboration between the original authors, two overlapping interactive networks were developed and designed using the co-author analysis of VOSviewer, as depicted in Fig. 5 and Fig. 6.

The circles in Fig. 5 indicate organizations and the graph means the connection between different departments. Fig. 6 presents the author cooperation relationship on SC, where the circles indicate authors, the color represents the clusters of authors with similar research topics, and the lines denote the connection strength between different authors. As shown in Fig. 5, the organizational collaboration Internet on SC contains 153 new items, 13 clusters, and 448 connections. In terms of link number, Harvard University's with 31 links is the most. It has the most cooperation with others in SC research, followed by Liberty Mutual Research Institute for Safety (links = 18), and John Hopkins University (links = 15). According to the link strength, Harvard University and Stanford university have the closest collaboration in SC research.

Fig. 7 shows the number of documents, links, citations, average publication year, and average citations in productive institutions with the top 15 of institutions according to the publications. Five of the fifteen institutions are situated in the USA and no single institution is from China. Queensland Univ Technol, Univ South Australia, and Univ s Australia are all situated in Australia. Harvard University published 38 papers and has 1685 total citations, listed as No.1 in all institutions in terms of the corresponding author's institutions (Fig. 7). Secondly, Univ Bergen is classified with 32 papers and 418 citations. Technion Israel Inst Technol has the most citations(3590). The average publication year is during 2010–2016 mainly. Surprisingly, Technion Israel Inst Technol is listed as No.1 in all institutions with the largest number of average citations, having three times more than Harvard University which has the highest number of papers. Therefore, we can make a summary that international cooperation in this field should be improved and

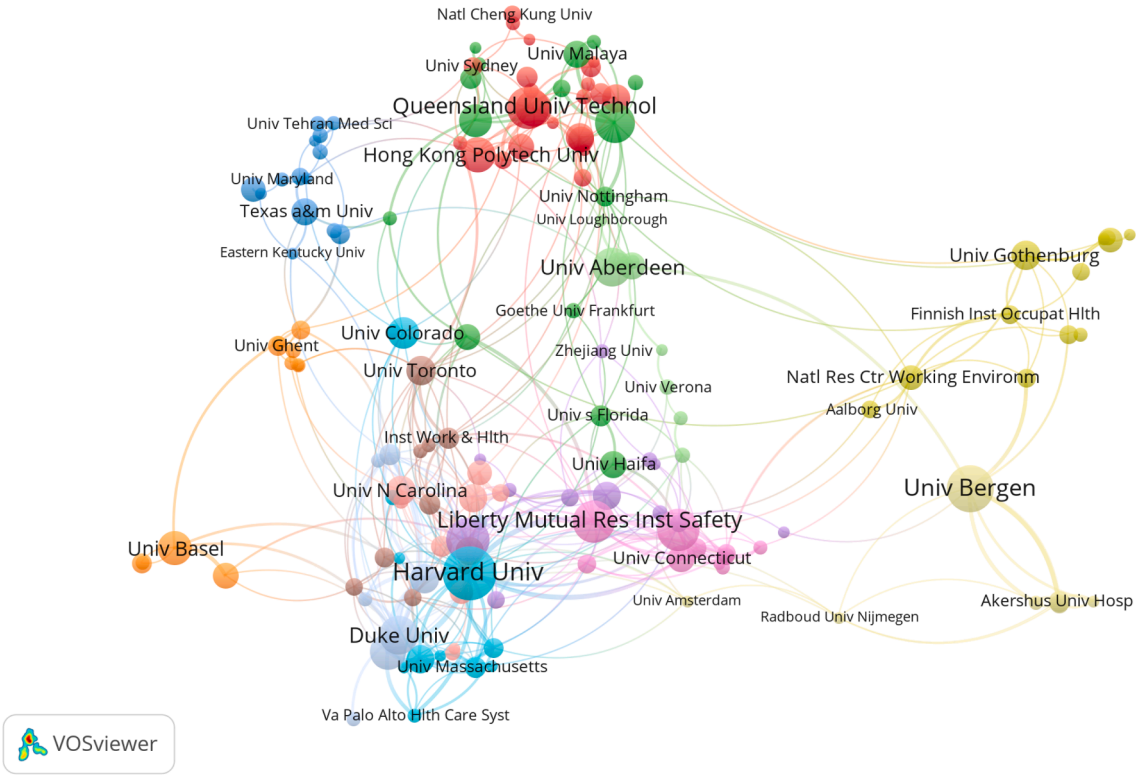

Fig. 5. Cooperation network between different institutions on SC research in WoS.

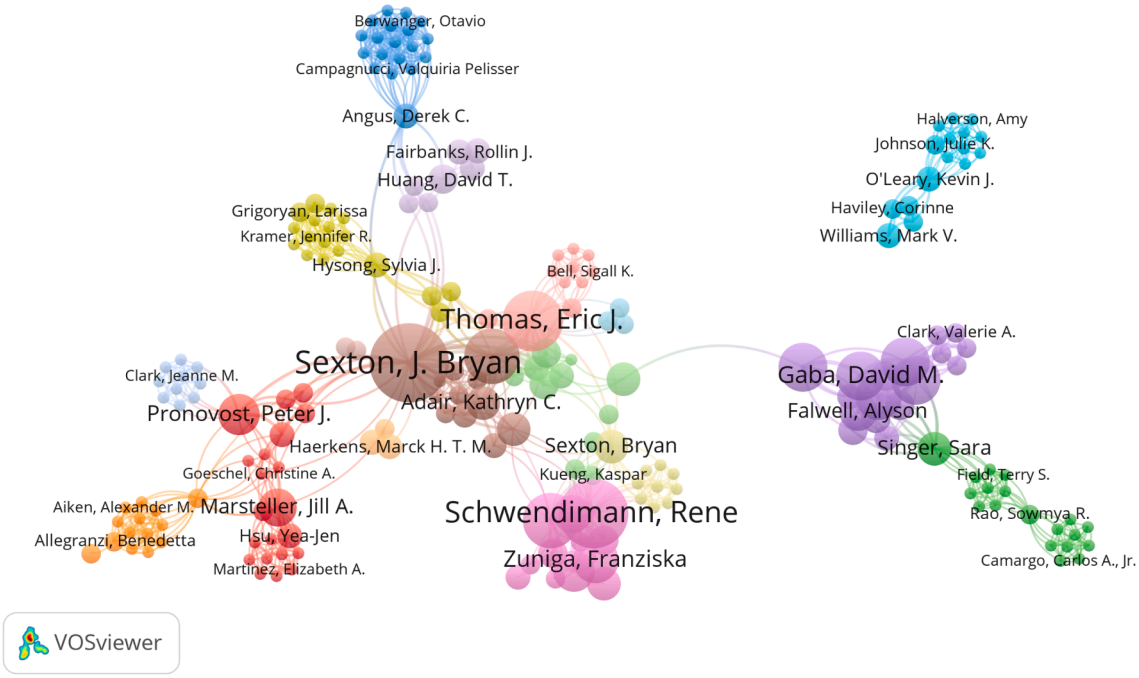

Fig. 6. Author cooperation network on SC research.

ameliorated in the future.

This paper analyzes the author's country, institution, number of published papers, H-index, and average citation of journals. Overall, 4830 authors published SC studies from 1980 to 2021. Table 3 lists the ten most published articles in SC. Dollard published the most articles in SC, followed by Huang and Sexton. Interestingly, six of the top ten authors come from the USA. The Zohar, Mearns, Sexton and Thomas are the most valuable in terms of number of citations and H-index.

Furthermore, in these productive institutions, a co-authorship network was developed to understand the author's cooperation relationship in this field (see Fig. 6). The colors represent the clusters of collaboration authors with analogous study topics. It is noteworthy that the small clusters which are not associated with each other have been cleared up from the network (Yang et al., 2019). As shown in Fig. 6,

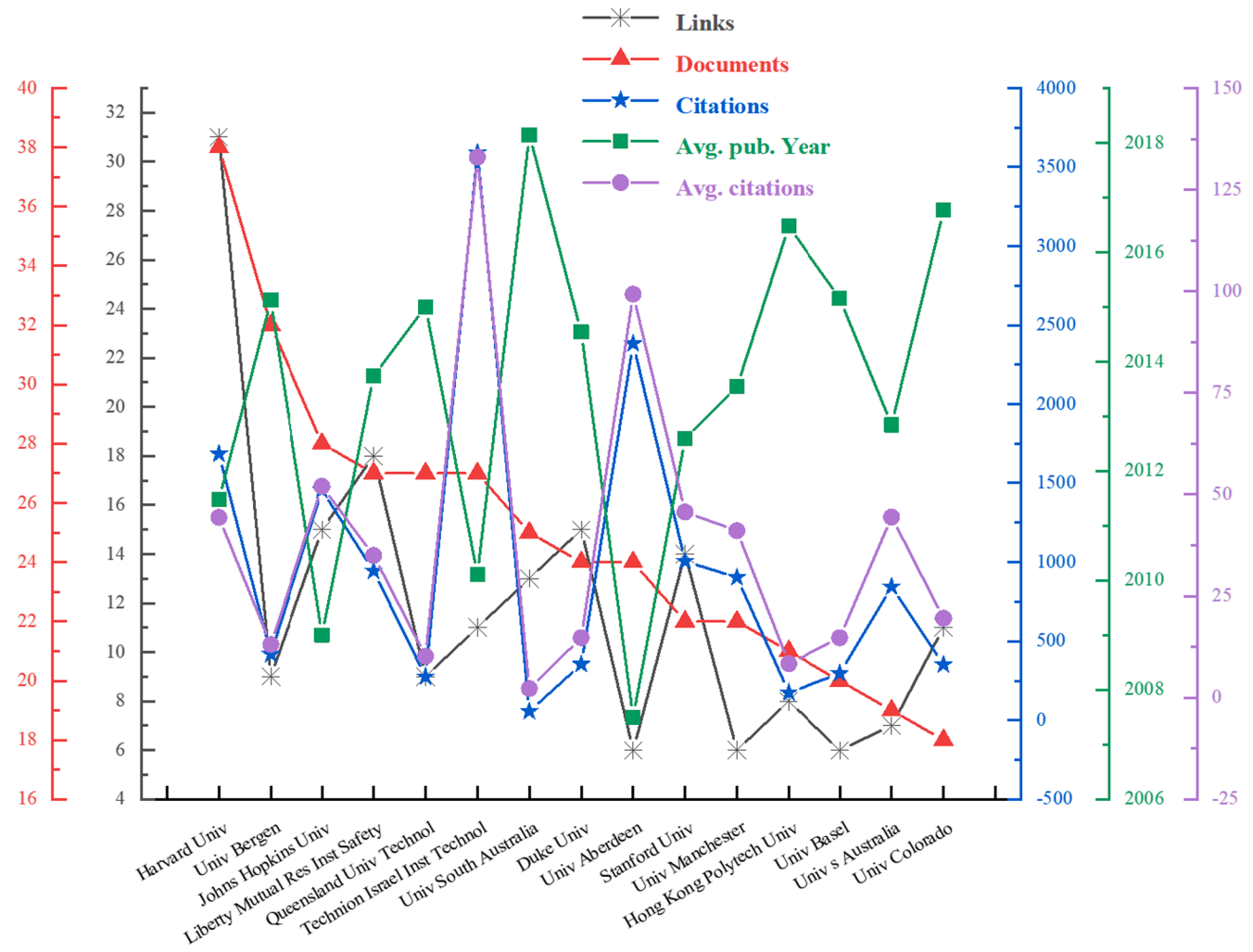

Fig. 7. The productive institutions that top 15 documents on SC.

Table 3
The top 10 prolific authors on SC.

Author	Country/Institute	No.	Average citations per publication	H-index
Dollard MF	Australia/University of South Australia	28	27.79	14
Huang YH	USA/Liberty Mutual Research Institute For Safety	22	7.88	9
Sexton JB	USA/Duke University	21	83.19	14
Zohar D	Israel/Technion Israel Institute of Technology	19	168.45	17
Mearns K	Scotland/University of Aberdeen	16	117.63	15
Thomas EJ	USA/University of Texas	15	74.47	11
Lee J	USA/Kansas State University	13	17.62	8
Schwendimann R	Switzerland/University of Basel	13	22.38	11
Arcury TA	USA/Wake Forest University	12	21.33	8
Chen PY	USA/Auburn University	12	42.17	11

Sexton, Schwendimann, and Thomas published most papers with other authors. In contrast, although Zohar and Mearns are the most active authors in SC research, they have less collaboration with other scholars. Nevertheless, co-authoring publications have positive effects on innovation in research and the exchange of ideas in academia (Zou et al., 2018). Therefore, the publication cooperation among authors should be strengthened.

3.5. Citation analysis

As a valid method to evaluate the influence and performance of some academic publications, a citation analysis is conducted by calculating the number of times that the papers have been quoted by other documents listed in WoS (Yang et al., 2019). Fig. 8 shows the most frequently cited publications in the SC field during 1980–2021. The most cited paper is titled "*Safety climate in industrial organizations: theoretical and applied implication*", and is authored by Zohar (1980) in the *Journal of Applied Psychology*, with a total of 1346 times cited. "*The Safety Attitudes Questionnaire: psychometric properties, benchmarking data, and emerging research*" (Sexton, 2006) published by *BMC Health Services Research* and "*The nature of safety culture: a review of theory and research*", authored by Guldenmund (2000) in *Safety Science*, are ranked No.2 and No.3, with respectively 916 and 915 citations, separately.

4. Keywords co-occurrence analysis

The keywords are related to the specific content of a publication, so keyword mining is very helpful to identify the key topics of SC scientific research. According to text mining, keywords and important professional terms can be obtained from article titles, introductions, keywords brought by the authors, and database index keywords, as well as co-

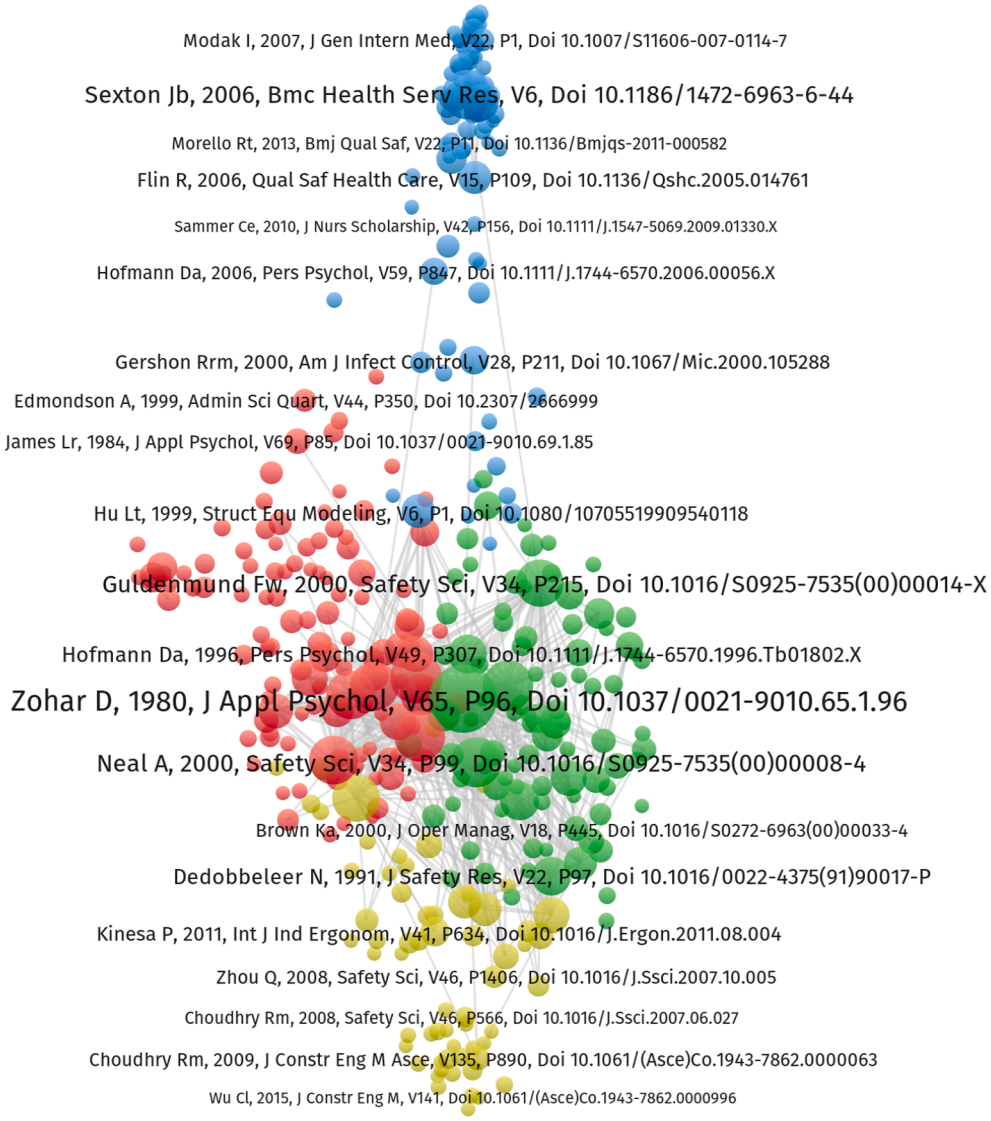

Fig. 8. The most frequently cited publications on SC in WoS.

occurrences in several publications (Van Eck and Waltman, 2014). Keywords with co-occurrence frequency greater than 10 are selected in Fig. 9, and a total of 240 keywords meet the conditions. Merge keywords with similar meanings, Eliminate meaningless keywords, and draw the keyword co-occurrence diagram. Keywords can be divided into five types according to the color of the keyword node in Fig. 9. As can be seen from Fig. 9, there are five different term clusters, which are described as cluster one (blue network), cluster two (yellow network), cluster three (red network), cluster four (green network), cluster five (purple network).

Fig. 9 shows the keyword network. The space in the middle of the circle gives the information content of the keyword relevance, and the size of the connection point indicates the frequency of the keyword occurrence. The overlap of connection points indicates how often this keyword occurs together in the networks of keywords. In addition, the keyword topographic map reflects how the keywords of the SC publication are gathered.

The blue cluster (cluster 1) includes 44 keywords. This cluster consists of keywords such as *job demands*, *job satisfaction*, *workplace*, *work*, *stress*, *burnout*, *employee engagement*, *metaanalysis* and *psychological health*. The most frequent keyword in the blue cluster is "work". We can see that the blue cluster spreads out around "work". Accordingly, it can be inferred that these publications focus on employees' job satisfaction beyond safety outcomes and health.

The yellow cluster (cluster 2) includes 29 keywords. The primary keywords in this cluster are *safety*, *health*, *injuries*, *risk*, *validation*, *environment*, *validity*, *occupational injury*, *risk factors*, *construction workers* and *universal precautions, etc.* The most frequent keyword in the yellow cluster is "health" and its occurrences are 133 with 153 links. It is obviously demonstrated that the research of health is the focus of this cluster.

The red cluster (cluster 3) is the largest cluster and consists of 61 keywords. The most collaborative keywords are *culture*, *climate*, *patient safety*, *teamwork*, *attitudes*, *outcomes*, *nurses*, *questionnaire*, *hospitals*, *care*, *organizational culture*, *quality*, *adverse events*, *framework*, *health-care*, and *psychometric properties.* This analysis reveals a real situation that this cluster concentrates on culture and climate research that emphasizes the practical application of the SC in health care.

The green cluster (cluster 4) is mainly around the keyword "safety climate" with the highest frequency among all the keywords. The other main keywords in the green cluster refer to *model*, *behavior*, *construction*, *workplace safety*, *perception*, *performance*, *accidents*, *industry*, *impact*, *risk perception*, *meta-analysis*, and *management*. Terms like "model" and "*meta*-analysis" indicate are related to methodology. Namely, the green cluster concentrates on the relationship between SC and safety behaviors/safety performance using measurement tools.

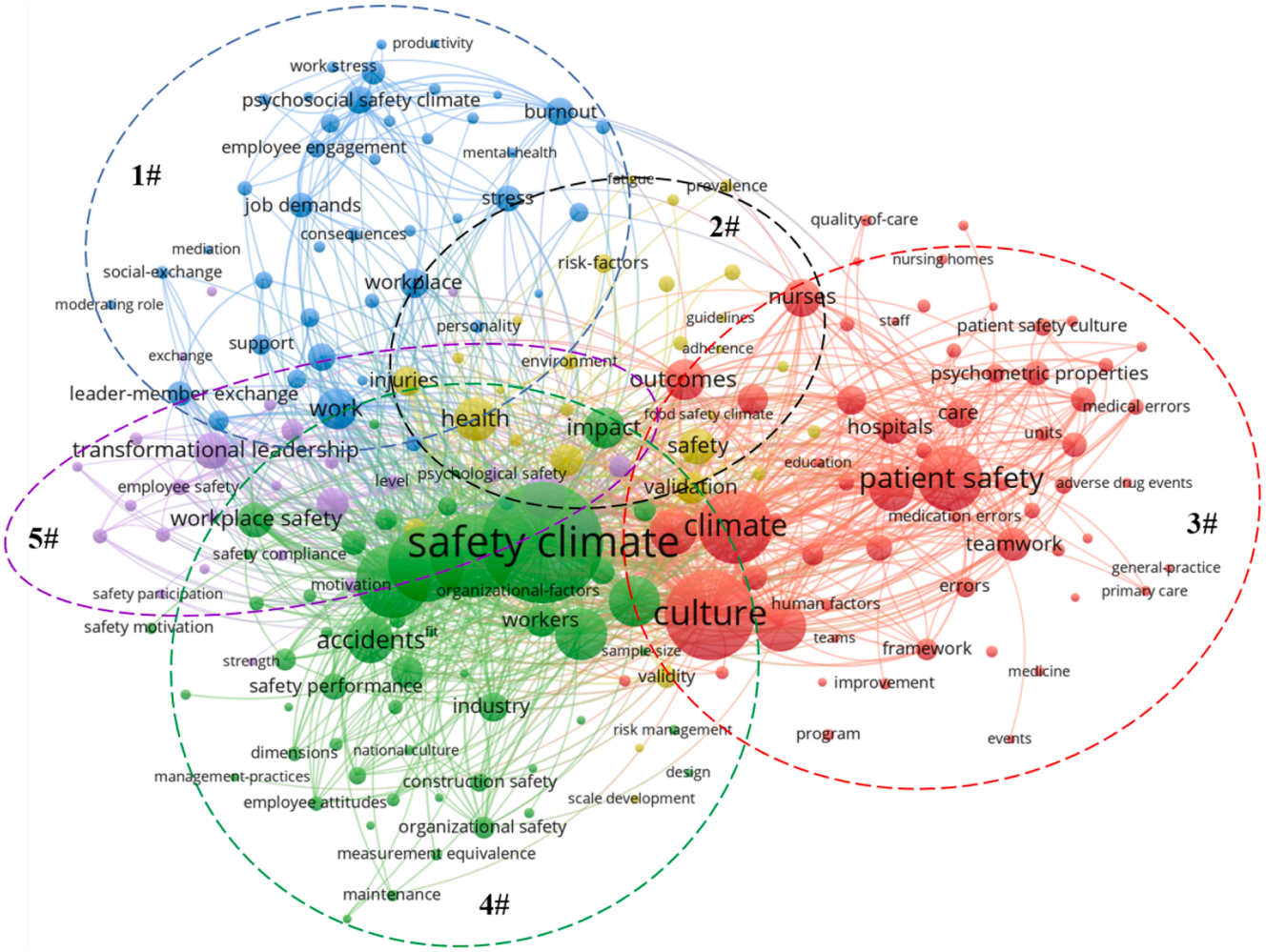

Fig. 9. Keywords co-occurrence analysis of SC publications.

The purple cluster (cluster 5) is the smallest cluster with 26 keywords. This cluster has a low degree of coherence. The most frequent keyword is "leadership" in this cluster and its occurrences are 132 and links are 173. The other primary keywords in this purple cluster are *organizations*, *transformational leadership*, *organizational climate*, *safety leadership*, *employee safety*, *antecedents*, *intervention*, and *motivation*. The workplace and organizational SC appear to be a focus of this cluster.

Fig. 10 presents the temporal changes of keywords in SC files. The average publication year of a term is indicated by the color of the term. In addition, this paper also provides a density view of the SC hot spot vocabulary from 1980 to 2005 and 2006–2021 to better understand the field (see Fig. 11). In addition, the 25 most important keywords in SC research from 1980 to 2021 are listed in Table 4. From Table 4 listed above, it can be concluded that most studies before 2005 concentrated on the conceptualization of SC (the hot terms comprising *accidents*, *model*, *culture*, *performance*, *behavior*, *attitudes*, *perceptions*, *organizational climate*, etc.). This phenomenon can be explained by the origin of the "safety climate". Generally, "safety climate" is cleared as "shared perceptions of employees about the safety of their work environment" (Hahn and Murphy, 2008), or "a measurable aspect (marker) or a surface manifestation of safety culture in an organization" (Huang et al., 2013; Murphy et al., 2018). Hence, the preliminary research themes in the SC research focused on "what are safety climate and how does it differ from safety culture" (Huang et al., 2010). In the most recent ten years, the notable research topics focused on testing theoretical SC models (hot terms referring to *impact*, *questionnaire*, *meta-analysis*, etc.). Zohar (2010) indicated that plentiful work about safety climate mainly concentrated on methodologies instead of theoretical and conceptual issues. Besides, the practical significance of SC has been attached great importance (corresponding terms such as *patient safety*, *health care*, *management*, *hospitals*, *construction*, *workplace safety*, etc.). Moreover, some new topics appeared in SC research, such as employees' job satisfaction, interventions to improve SC, and psychological safety climate.

5. Discussion

5.1. Summary of main research in safety climate

A comprehensive evaluation of the documents on SC was conducted using bibliometric analysis. In general, a variety of SC studies had attracted increasing concern in the recent thirty years. The USA is always the leader, followed by Australia and UK. In contrast, some developing nations have made little contribution to SC studies, including African, and Middle Eastern countries. Similarly, researchers from these countries such as the USA, Australia, China, and the UK played a remarkable role in international cooperation. Concerning the journal analysis, SC articles mostly originated from Safety Science. In terms of citation analysis, the most frequently introduced content mentions a physical model that connects transformational leadership with special safety and job damage, which provides a new idea for SC scientific research technicians. SC scientific research is multi-course, including "Engineering projects", "Psychological knowledge", "Social Economics of Business Services" and "Nursing majors". Therefore, it is

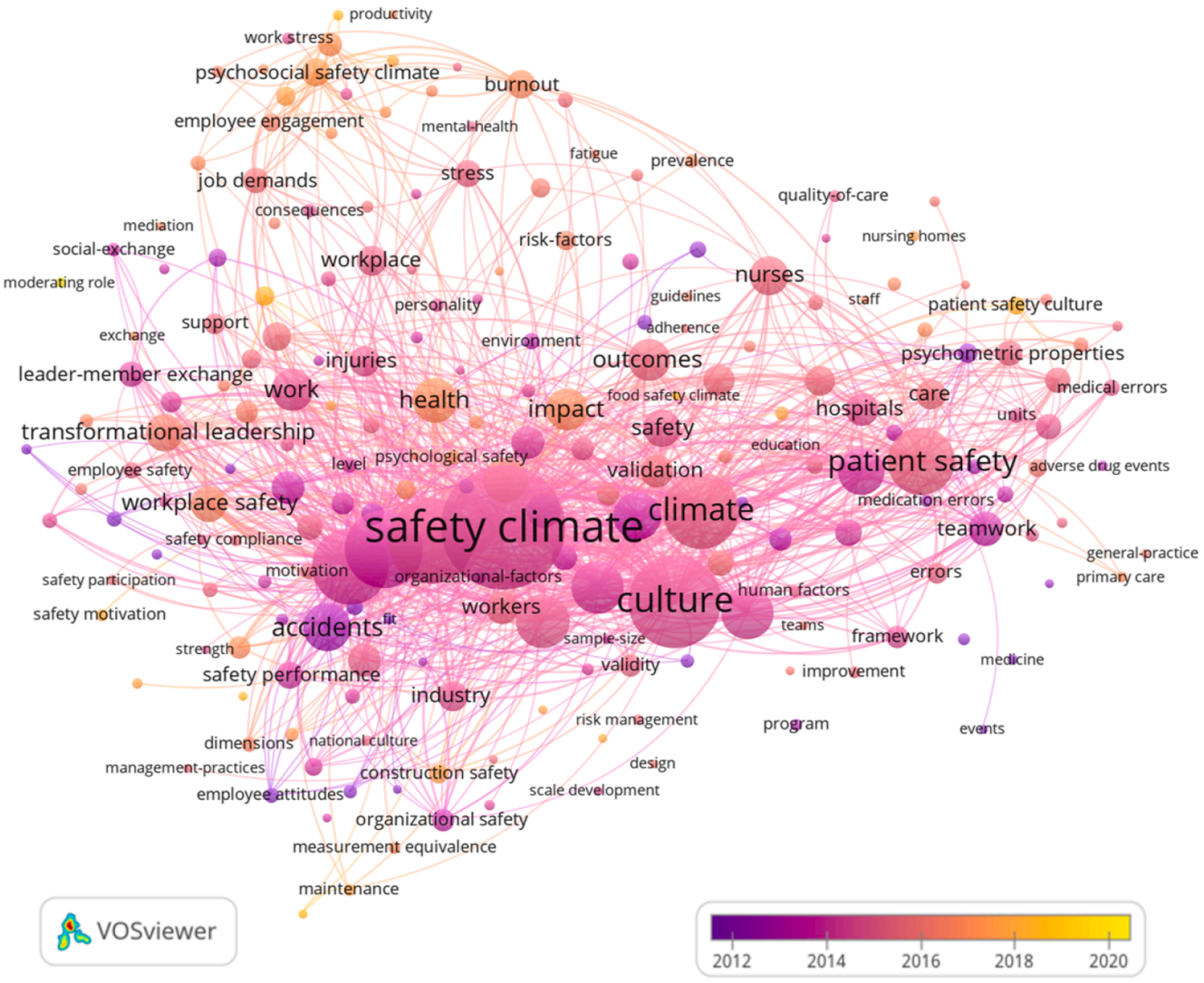

Fig. 10. Keywords analysis of SC publications with time information.

necessary to encourage experts and scholars in various scientific fields to communicate and exchange professional knowledge on SC theme styles. As far as the theme style of scientific research in the SC industry is concerned, “leadership”, “safety performance”, “personal behavior” and “climate” are the most commonly used keywords. In other words, many safety publications are centralized on the multi-faceted model. Comparably, general scientific research is dedicated to detecting the hazards of the personal behavior of special leaders to the safety performance evaluation of employees. Today’s SC scientific research focuses on leadership styles rather than practical activities to build leadership capabilities (Besikçi, 2019), and cannot express the harm of the environment to practical activities (Pilbeam et al., 2016). Dollard has the largest number of publications related to SC, focusing on psychosocial safety climate(PSC). Some warnings of increased psychosocial risks resulting in stress and burnout. Therefore, PSC offers a value and system frame, which has been used to better understand how management values affect the health and well-being of work design and workers (Dollard, 2022; McLinton et al., 2018). Some recent papers also discuss the research status on SC. For instance, the importance of safety and SC increases with complexities of technologies and their potential for having a short-term and long-term effect on various aspects of the well-being of nature and life.

5.2. Association and difference between safety climate and safety culture

In the field of safety research, although scholars generally believe that SC and safety culture were different concepts, many overlapping definitions of the two concepts were put forward in the literature. As a result, the concepts of SC and safety culture were often confused in theory and practice despite with distinct etymology (Cox and Flin, 1998). From our research on the keywords, it can be found that no matter at what stage, most of the keywords on SC are always related to safety culture, demonstrating the tightness of SC and safety culture research.

Both SC and safety culture reflect the social attributes of individuals and organizations in different degrees. They emphasize the importance of cognition, awareness, and beliefs to the construction of safety culture and climate. Also, they belong to the humanities and social sciences research, with typical interdisciplinary characteristics (Kalteh et al., 2018; Li et al., 2022). Additionally, both focus on different levels of management and implementation activities, assuming that the safety state can be corrected and improved through management. Therefore, they are in line with the definition of organizational culture and climate of modern enterprise management, having the content of management science and highlighting characteristics of safety discipline. However, there exist differences between SC and safety culture. Hale (2000) indicated that safety culture is a whole value and practice, and it has a

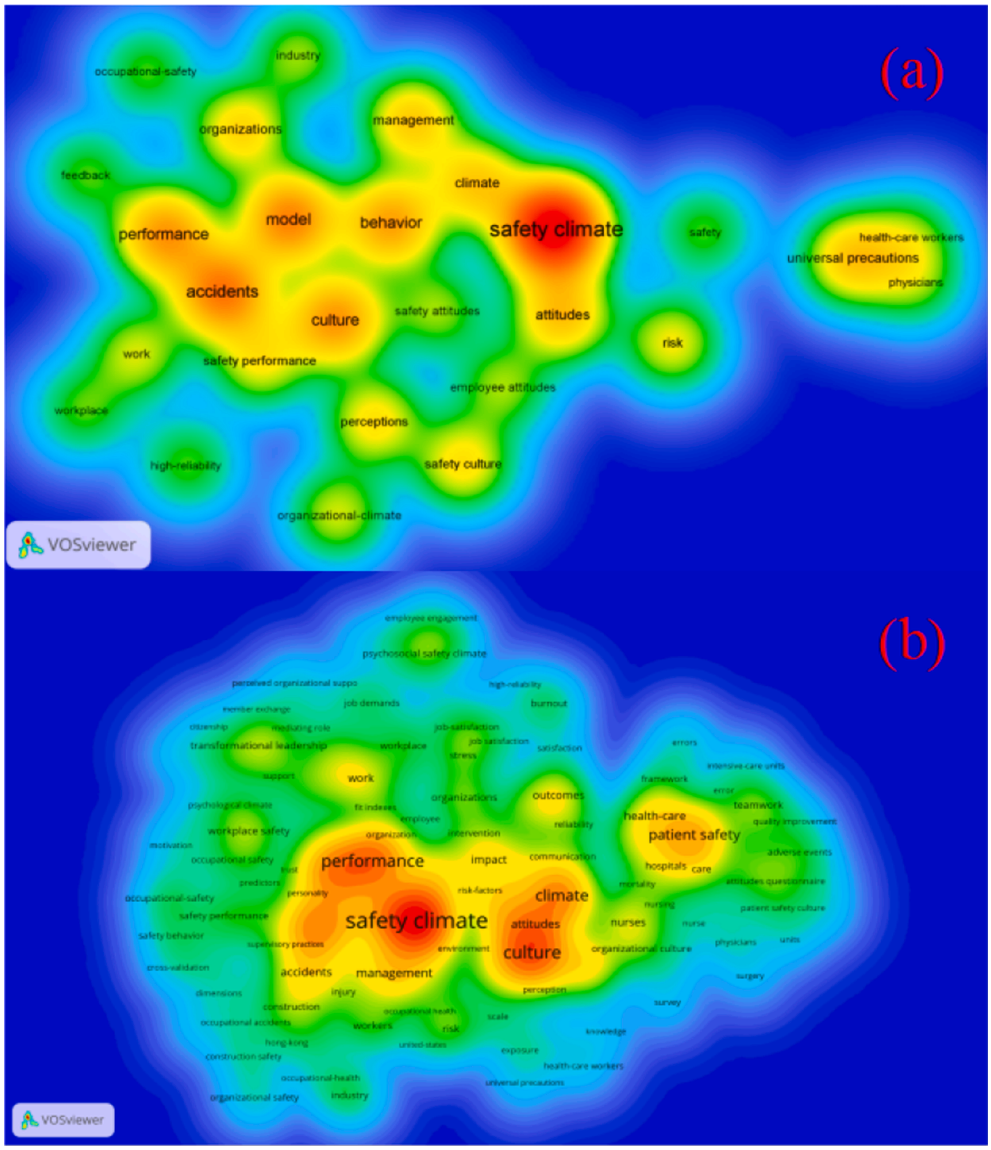

Fig. 11. Research topic evolution over time in SC research: (a) 1980–2005, (b)2006–2021.

strong impermanent relationship with the company. These values and practices are stable and difficult to be observed. Instead, the corporate SC is easier to be observed. Wiegmann et al.(2002) stated that the SC is a miniature of safety culture at a certain moment, and SC shows an organization's view of safety culture. Safety culture contains potential safety beliefs, safety values and safety attitudes, etc., while SC is closer to the enterprise production operation state, with the cognitive characteristics of the working environment, production implementation, organizational policies and management. Safety culture research and application focus on the macro-level and belongs to theoretical research while SC emphasizes the micro-level of the enterprise, with empirical and technical applications.

5.3. The research limitations

The concept of SC is still in its initial stage of development. In the past few decades, the analysis of SC can be divided into two categories (Luo, 2020): the development trend of measuring instruments, and the creation of theoretical models. Few studies use SC as a result variable to clarify which most affect the overall SC level. The use of shortened SC scales has the potential to increase the chances of expanding our understanding of the relationships between SC and other constructs.

When explaining the results of this study, we also take into account certain limitations. Firstly, searches are performed only on files in WoS. Although WoS is one of the largest databases in the world, it does not contain all research on the SC. PubMed, Scopus, Sprint and MySQL can be used in combination. Also, there are at least 420 publications on SC in the Chinese National Knowledge Infrastructure (CNKI) database, which are excluded in this bibliometric analysis. Secondly, some publications were incorporated, although they are involved in the subject of SC. Finally, this paper only analyzes the existing classifications on the WoS, resulting in lack of experience, such as background and so on. In view of the shortcomings of this paper, it is recommended to conduct a deeper content analysis.

5.4. Future needs of safety climate research

Some positive aspects could be derived from the results of bibliometric analysis and the relevant research prospects of SC are as follows:

(1) Based on the geographical distribution of publications and cooperation network analysis, more international cooperation in the SC domain could be strengthened in the future.

Table 4
Distribution of top 25 keywords of SC.

Rank	1980–2005 Terms	F	2006–2021 Terms	F	Global Terms	F
1	Safety climate	36	Safety climate	654	Safety climate	690
2	Accidents	19	Culture	417	Culture	433
3	Model	18	Performance	358	Performance	374
4	Culture	16	Model	304	Model	322
5	Performance	16	Climate	304	Behavior	318
6	Behavior	15	Behavior	303	Climate	315
7	Attitudes	12	Patient safety	254	Patient safety	257
8	Management	11	Management	167	Management	178
9	Climate	11	Safety culture	163	Safety culture	172
10	Universal precautions	11	Perceptions	160	Perceptions	169
11	Organizations	10	Health-care	136	Accidents	148
12	Safety culture	9	Attitudes	134	Attitudes	146
13	Safety performance	8	Health	131	Health-care	137
14	Risk	8	Leadership	130	Health	133
15	Work	7	Accidents	129	Leadership	132
16	Organizational -climate	7	Outcomes	121	Outcomes	122
17	Employee attitudes	6	Impact	118	Impact	121
18	Industry	6	Work	110	Work	117
19	Safety attitudes	6	Nurses	103	Nurses	106
20	Occupational-safety	5	Safety	92	Safety	97
21	Feedback	5	Teamwork	82	Workplace safety	92
22	Workplace	5	Validation	82	Organizations	85
23	High-reliability	5	Workers	81	Teamwork	84
24	Health-care work	5	Hospitals	77	Validation	82
25	Physicians	5	Organizations	75	Workers	82

F represents the frequency of each term.

(2) Given the analysis of keywords, SC research in recent years mainly concentrated on performance, model, behavior, patient safety, management, accidents, health care, and leadership. Nowadays, there are already studies about safety leadership, supervisor, SC, and tourism. With the development of big data, future researchers should explore the practical application of SC in other fields, such as education industries, emergency sector, logistics transportation, intelligent manufacturing, etc.

(3) It is crucial to integrate some innovative methods in the domain of SC research. Therefore, future research should provide a large sample quantity, multi-level, and multi-method integration research to obtain important results. At the same time, this paper adopts the VOSviewer for bibliometric analysis, but there are still many other software tools for bibliometric analysis (Pan et al., 2018; Yang and Qiu, 2019), such as CreateSpace, CitNetExplorer, HistCite, Bibexcel, and Network Workbench Tool, etc. In the future, a variety of methods are used to conduct comparative analysis of SC research.

(4) Given the conceptual and methodological limitations of SC, systems thinking is useful when understanding SC across work systems (Goode et al., 2014; Donovan et al., 2018). Gotcheva et al. (2021) have applied systems thinking to the safety culture approach by the Finnish nuclear safety research. Thus, systems thinking could be applied to SC domain in further research in the future.

(5) With the development of human society, SC is considered important for enhancing safety performance, especially for developing countries. According to the results of this paper, most researchers are from developed countries. Therefore, future research in the SC domain should be impelled in the undeveloped and developing countries or regions, such as parts of Africa and the Middle East.

6. Conclusions

A review of the publications and distribution of the relevant safety climate (SC) was carried out, including information related to document attributes, country/region, organization, publications, author's true identity, citations, and keywords. All in all, from 1980 to 2021, the total number of SC graduation thesis increased dramatically. The USA, Australia, and China are the top three countries with the largest productivity in SC publications. Accordingly, the USA has a lot of collaboration with Canada and the UK. Similarly, Australia has plenty of cooperation with China. Harvard University and the University of South Australia are firmly at the forefront of the organization given the total number of articles on SC. *Safety Science*, *Accident Analysis and Prevention*, and *Journal of Safety Research* are the top three publications that publish the most articles related to SC. Dollard is the author with the largest total number of publications related to safety climate. Dollard s research mainly focuses on psychosocial safety climate(PSC), which acts as a guiding index of adverse health and motivational outcomes at work and further flow-on effects on patients and plays a primary prevention role in safeguarding mental health at work. A keyword analysis indicates that most studies concentrate on the conceptualization of SC before 2005, including *accidents, model, safety performance, safety culture, safety behavior, etc.* The research topics in recent fifteen years mainly focus on testing theoretical SC models and practical applications, referring to *questionnaires and meta-analyses.* Besides, *patient safety, management, and health care* are prevalent topics. Moreover, the attention in the research field of SC has shifted from earlier topics of concepts and models to applications.

The results in this study can provide significant information for coming researchers to better understand the development trends associated with SC research. Meanwhile, the present work is also helpful for researchers to seek cooperation possibility with other scholars and institutions, and to select suitable journals to publish papers in the domain of SC.

CRediT authorship contribution statement

Fuqiang Yang: Writing – review & editing, Supervision, Resources, Conceptualization. **Yujie Huang:** Writing – original draft, Methodology. **Jing Tao:** Software, Data curation. **Genserik Reniers:** . **Chao Chen:** Writing – review & editing, Visualization, Supervision.

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.

Data availability

Data will be made available on request.

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References

Alruqi, W.M., Hallowell, M.R., Techera, U., 2018. Safety climate dimensions and their relationship to construction safety performance: A meta-analytic review. Saf. Sci. 109, 165–173.

Bamel, U.K., Pandey, R., Gupta, A., 2020. Safety climate: Systematic literature network analysis of 38 years (1980–2018) of research. Accid. Anal. Prev. 135, 105387.

Catharina, A., Mdtab, C., Jennifer, C., Matthew, J.G., Daniel, H., Gregory Neely, G., Malgorzata, L., Shinichi, N., 2021. PFAS exposure of humans, animals and the environment: Protocol of an evidence review map and bibliometric analysis. Environ. Int. 158, 106973.

Chen, D., Liu, Z., Luo, Z.H., Webber, M., Chen, J., 2016. Bibliometric and visualized analysis of emergy research. Ecol. Eng. 90, 285–293.
Chen, Chao, Li, Changjun, Reniers, Genserik, Yang, Fuqiang, 2021. Safety and security of oil and gas pipeline transportation: A systematic analysis of research trends and future needs using WoS. Journal of Cleaner Production 279, 123583. https://doi.org/10.1016/j.jclepro.2020.123583.
Cooper, M.D., Phillips, R.A., 2004. Exploratory analysis of the safety climate and safety behavior relationship. J. Saf. Res. 35, 497–512.
Cox, S., Flin, R., 1998. Safety culture: Philosopher's stone or man of straw? Work Stress 12 (3), 189–201.
Davarzani, H., Fahimnia, B., Bell, M., Sarkis, J., 2016. Greening ports and maritime logistics: a review. Transport. Res. Part D: Transp. Environ. 48, 473–487.
Dollard, M., 2022. Psychosocial safety climate (PSC) in the future of work. Saf, Health Work, p. 13.
Dollard, M.F., Tuckey, M.R., Dormann, C., 2012. Psychosocial safety climate moderates the job demand-resource interaction in predicting workgroup distress. Accid. Anal. Prev. 45, 694–704.
Donovan, S.L., Salmon, P.M., Horberry, T., Lenne, M.G., 2018. Ending on a positive: examining the role of safety leadership decisions, behaviours and actions in a safety critical situation. Appl. Ergon. 66, 139–150.
González-Benito, J., Lannelongue, G., Alfaro-Tanco, J.A., 2013. Study of supply-chain management in the automotive industry: a bibliometric analysis. Int. J. Prod. Res. 51, 3849–3863.
Goode, N., Salmon, P.M., Lenne, M.G., Hillard, P., 2014. Systems thinking applied to safety during manual handling tasks in the transport and storage industry. Accid. Anal. Prev. 68, 181–191.
Gotcheva, N., Oedewald, P., Ylönen, M., 2021. Systems thinking applied to safety culture approach in Finland. Human Factors in the Nuclear Industry 73–91.
Gou, X.Q., Liu, H., Qiang, Y.J., Lang, Z.H., Wang, H.N., Ye, D., Wang, Z.W., Wang, H., 2022. In-depth analysis on safety and security research based on system dynamics: a bibliometric mapping approach-based study. Saf. Sci 147, 105617.
Guo, B.H.W., Yiu, T.W., González, V.A., 2016. Predicting safety behavior in the construction industry: Development and test of an integrative model. Saf. Sci. 84, 1–11.
Hale, A.R., 2000. Culture's confusions. Saf. Sci. 34, 1–14.
Ho, Y.S., 2008. Bibliometric analysis of biosorption technology in water treatment research from 1991 to 2004. Int. J. Environ. Pollut. 34 (1), 1–13.
Huang, Y.H., Chen, P.Y., Grosch, J.W., 2010. Safety climate: New developments in conceptualization, theory, and research. Accid. Anal. Prev. 42, 1421–1422.
Huang, Y.H., Zohar, D., Robertson, M.M., Garabet., A., Lee, J., Murphy, L.A., 2013. Development and validation of safety climate scales for lone workers using truck drivers as exemplar. Transp. Res. Pt. F-Traffic Psychol. Behav. 17(Part F), 5-19.
Jin, R., Zou, P.X.W., Piroozfar, P., et al., 2019. A Science Mapping Approach Based Review of Construction Safety Research. Saf. Sci. 113, 285–297.
Kalteh, H.O., Mortazavi, S.B., Mohammadi, E., Salesi, M., 2018. The relationship between safety culture and safety climate and safety performance: a systematic review. Int. J. Occup. Saf. Ergon, 1–31.
Kasim, H., Hassan, C.R.C., Hamid, M.D., Emami, S.D., Danaee, M., 2019. The relationship of safety climate factors, decision making attitude, risk control, and risk estimate in Malaysian radiation facilities. Saf. Sci. 113, 180–191.
Kim, N.K., Rahim, N.F.A., Iranmanesh, M., Foroughi, B., 2019. The role of the safety climate in the successful implementation of safety management systems. Saf. Sci. 118, 48–56.
Kvalheim, S.A., Dahl, O., 2016. Safety compliance and safety climate: A repeated cross-sectional study in the oil and gas industry. J. Saf. Res. 59, 33–41.
Landström, H., Harirchi, G., Aström, F., 2012. Entrepreneurship: exploring the knowledge base. Res. Pol. 41, 1154–1181.
Lee, J., Huang, Y.H., Cheung, J.H., et al., 2019. A systematic review of the safety climate intervention literature: Past trends and future directions. J. Occup. Health Psychol. 24 (1), 66.
Li, J., Hale, A., 2016. Output distributions and topic maps of safety related journals. Saf. Sci. 82, 236–244.
Li, J., Goerlandt, F., Reniers, G., 2021. An overview of scientometric mapping for the safety science community: Methods, tools, and framework. Saf. Sci. 134, 105093.
Li, J., Goerlandt, F., van Nunen, K., Ponnet, K., Reniers, G., 2022. Conceptualizing the Contextual Dynamics of Safety Climate and Safety Culture Research: A Comparative Scientometric Analysis. Int. J. Environ. Res. Public Health 19 (2).
Li, J.F., Zhang, Y.H., Wang, X.S., Ho, Y.S., 2009. Bibliometric analysis of atmospheric simulation trends in meteorology and atmospheric science journals. Croat. Chem. Acta. 82, 695–705.
Liu, X.X., Huang, G.X., Huang, H.Q., Wang, S.Y., Xiao, Y.N., Chen, W.Q., 2015. Safety climate, safety behavior, and worker injuries in the Chinese manufacturing industry. Saf. Sci. 78, 173–178.
Liu, W.H., Zheng, J.W., Wang, Z.R., 2021. A bibliometric review of ecological research on the Qinghai-Tibet Plateau, 1990–2019. Ecol. Inform. 64, 101337.
Luo, T., 2020. Safety climate: Current status of the research and future prospects. Journal of Safety Science and Resilience 1, 106–119.
Ma, Q.G., Yuan, J.P., 2009. Exploratory study on safety climate in Chinese manufacturing enterprises. Saf. Sci. 47, 1043–1046.
McLinton, S.S., Dollard, M.F., Tuckey, M.R., 2018. New Perspectives on Psychosocial Safety Climate in Healthcare: A mixed methods approach. Saf. Sci. 109, 236–245.
Memarbashi, E., Mohammadizadeh, F., Boroujeny, Z.A., Lotfi, M., Khodayari, M.T., Nasiri, E., Akhuleh, O.Z., 2021. The relationship between nurses' safety climate in the operating room and occupational injuries: A predictive correlational study. Perioperative Care and Operating Room Management 24, 100206.
Murphy, L.A., Robertson, M.M., Carayon, P., 2014. The next generation of macro ergonomics: Integrating safety climate. Accid. Anal. Prev. 68, 16–24.
Murphy, L.A., Robertson, M.M., Huang, Y.H., Jeffries, S., Dainoff, M.J., 2018. A sociotechnical systems approach to enhance safety climate in the trucking industry: Development of a methodology. Appl. Ergon. 66, 82–88.
Newaz, M.T., Davis, P., Jefferies, M., Pillay, M., 2019. The psychological contract: A missing link between safety climate and safety behaviour on construction sites. Saf. Sci. 112, 9–17.
O'Connor, P., Buttrey, S.E., O'Dea, A., Kennedy, Q., 2011. Identifying and addressing the limitations of safety climate surveys. J. Saf. Res. 42, 259–265.
Pan, X.L., Yan, E., Cui, M., Hua, W.N., 2018. Examining the usage, citation, and diffusion patterns of bibliometric mapping software: A comparative study of three tools. J. Informetr. 12, 481–493.
Pandit, B., Albert, A., Patil, Y., Al-Bayati, A.J., 2019. Impact of safety climate on hazard recognition and safety risk perception. Saf. Sci. 113, 44–53.
Payne, S.C., Bergman, M.E., Beus, J.M., Rodríguez, J.M., Henning, J.B., 2009. Safety climate: Leading or lagging indicator of safety outcomes? J. Loss Prev. Process Ind. 22, 735-739.
Pilbeam, C., Doherty, N., Davidson, R., Denyer, D., 2016. Safety Leadership Practices for Organizational Safety Compliance: Developing a research agenda from a review of the literature. Saf. Sci. 86, 110–121.
Quinn, M.R., Eric, V.W., 2019. Trends and perspectives on the use of animal social network analysis in behavioural ecology: a bibliometric approach. Anim. Behav. 149, 77–87.
Reason, J.T., 1997. Managing the Risks of Organizational Accidents. Actoolkit. unprme.org 43 (12), 147–181.
Reniers, G.L.L., Cremer, K., Buytaert, J., 2011. Continuously and simultaneously optimizing an organization's safety and security culture and climate: the Improvement Diamond for Excellence Achievement and Leadership in Safety & Security (IDEAL S&S) model. J. Clean Prod. 19, 1239–1249.
Russell, D.W., Russell, C.A., Lei, Z., 2022. Development and testing of a tool to measure the organizational safety climate aboard US Navy ships. J. Saf. Res. 80, 293–301.
Schbel, S., Mohammed, S., Janson, A., 2021. Two decades of game concepts in digital learning environments -A bibliometric study and research agenda. Comput. Educ. 173, 104–296.
Shea, T., De, C.H., Vu, T., et al., 2021. How is safety climate measured? A review and evaluation. Saf. Sci. 143, 105413.
Shen, Y.Z., Tuuli, M.M., Xia, B., Koh, T.Y., Rowlinson, S., 2015. Toward a model for forming psychological safety climate in construction project management. Int. J. Proj. Manag. 33, 223–235.
Sigman, M., 2011. A meta-analysis of meta-analyses. Fertil. Steril. 96 (1), 11–14.
Silva, S., Lima, M.L., Baptista, C., 2004. OSCI: an organisational and safety climate inventory. Saf. Sci. 42, 205–220.
Strozzi, F., Colicchia, C., Creazza, A., Noè, C., 2017. Literature review on the 'Smart Factory' concept using bibliometric tools. Int. J. Prod. Res. 55, 6572–6591.
Sun, L.J., Rahwan, I., 2017. Coauthorship network in transportation research. Transport. Res. Part A: Pol. Pract. 100, 135–151.
Taddeo, R., Simboli, A., Vincenzo, F.D., Ioppolo, G., 2019. A bibliometric and network analysis of Lean and Clean(er) production research (1990/2017). Sci. Total Environ. 653, 765–775.
Tao, J., Qiu, D.Y., Yang, F.Q., Duan, Z.P., 2020a. A bibliometric analysis of human reliability research. J. Clean Prod. 260, 121041.
Tao, J., Yang, F.Q., Qiu, D.Y., Reniers, G., 2020b. Analysis of safety leadership using a science mapping approach, Process Saf. Environ. Protect. 140, 244–257.
van Eck, N.J., Waltman, L., 2010. Software survey: VOSviewer, a computer program for bibliometric mapping. Scientometrics 84 (2), 523–538.
Wang, B., Wu, C., Kang, L.G., Reniers, G., Huang, L., 2018. Work safety in China's Thirteenth Five-Year plan period (2016–2020): Current status, new challenges and future tasks. Saf. Sci. 104, 164–178.
Wiegmann, D.A., Zhang, H., von Thaden, T.L., Sharma, G., Mitchell, A.A., 2002. A Synthesis of Safety Culture and Safety Climate Research. for the Federal Aviation Administration Atlantic City International Airport, NY. Technical Report ARL02-3/FAA-02-2.
Xu, J., Ge, Y., Qu, W.N., et al., 2018. The mediating effect of traffic safety climate between pedestrian inconvenience and pedestrian behavior. Accid. Anal. Prev. 119, 155–161.
Yang, F., 2012. Exploring the information literacy of professionals in safety management. Saf. Sci. 50 (2), 294–299.
Yang, L., Chen, Z., Liu, T., Gong, Z., Yu, Y., Wang, J., 2013. Global trends of solid waste research from 1997 to 2011 by using bibliometric analysis. Scientometrics 96, 133–146.
Yang, F., Qiu, D., 2019. Exploring coal spontaneous combustion by bibliometric analysis. Process. Saf. Environ. Prot. 132, 1–10.
Yang, Y.F., Reniers, G., Chen, G.H., Goerlandt, F., 2019. A bibliometric review of laboratory safety in universities. Saf. Sci. 120, 14–24.
Zarei, E., Khakzad, N., Reniers, G., Akbari, R., 2016. On the relationship between safety climate and occupational burnout in healthcare organizations. Saf. Sci. 89, 1–10.
Zhou, C.F., 2017. Comparative study of commonly used software for bibliometrics. Central China Normal University.
Zohar, D., 1980. Safety climate in industrial organizations: theoretical and applied implications. J. Appl. Psychol. 65, 96–102.
Zohar, D., 2010. Thirty years of safety climate research: Reflections and future directions. Accid. Anal. Prev. 42, 1517–1522.
Zou, X., Yue, W.L., Vu, H.L., 2018. Visualization and analysis of mapping knowledge domain of road safety studies. Accid. Anal. Prev. 118, 131–1114.