Analysis of safety leadership using a science mapping approach

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Abstract

It has been increasingly recognized that safety leadership can effectively contribute to organizational safety, so a lot of attention is paid to safety leadership studies in recent years. In order to understand the current status and development trends of research in safety leadership field around the world, a science mapping analysis of scientific publications on safety leadership was conducted via the Web of Science Core Collection database. Overall, a total of 238 documents on safety leadership were collected, involving 622 authors, 140 journals, 40 countries, and 388 institutes between 1999 and 2018. The studies associated with safety leadership have been growing from 3 in 1999 to 126 in 2018. The USA, UK, and Canada play important roles in safety leadership research, while further international cooperation should be strengthened in the future. Kelloway, Conchie, and Flin are the most active researchers in this field. With respect to the main sources of safety leadership publications, the *Safety Science* journal ranks first with 23 articles, followed by the *International Journal of Psychology*, and the *Journal of Nursing Management*. In addition, the University of Aberdeen (UK) is the most productive research institute with respect to safety leadership research. In terms of the frequency of keywords, *safety performance*, *transformational leadership*, *member exchange*, *transactional leadership*, and *safety climate* are the hottest topics in safety leadership research. The primary themes in safety leadership research concentrate on empiric supports of leadership on safety performance, various leadership styles applied in safety, specific applications of safety leadership in health care, and the correlation between safety leadership and safety climate. Additionally, there are new research topics appearing in recent three years, associated with psychological safety, authentic leadership, ethical leadership, charismatic leadership, empowering leadership.

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Keywords

Safety leadership
Safety performance
Bibliometric mapping
Scientific knowledge

1. Introduction

Recent years have witnessed an increasing concern on occupational health and safety performance in high-risk organizations, such as the shipping industry (Kim and Gausdal, 2017), construction projects (Wu et al., 2016), nuclear power plants (Martínez-Córcoles et al., 2013), petrochemical industries (Wu et al., 2011; Chen et al., 2019a, b), container terminal operations (Lu and Yang, 2010), mining (Donovan et al., 2018), etc. Although an improved safety performance has been acquired in many organizations nowadays, further efforts should be made to prevent the occurrence of workplace accidents. Occupational safety is dependent on various factors (Fernández-Muñiz et al., 2017; Guo et al., 2016; Molnar et al., 2019), including human behaviors, supervision, preconditions, and organizational factors. However, a large number of studies indicate that organizational leaders play a pivotal role in promoting safety-related effects in the workplace (Donovan et al., 2018; Fernández-Muñiz et al., 2017; Künzle et al., 2010; Molnar et al., 2019). For instance, Wu et al. (2011) applied empirical data to support the viewpoint that safety leadership (SL) shows a positive impact on safety climate and safety performance. Fernández-Muñiz et al. (2017) found that SL has a positive effect on safety incentives. Similarly, Mullen et al. (2017) concluded that leadership was significantly and positively related to employee safety attitudes, safety compliance, and safety participation. Accordingly, SL is considered to be ever important to the improvement of safety performance in diverse organizations, resulting in increasing research on SL. Kapp (2012) investigates the effect of the leadership practices of first-line supervisors on the employees' safety behavior. Also, contextual influences were identified to explore the factors that contribute to SL behaviors (Conchie et al., 2013). SL originated from organizational leadership studies, and it was developed to identify the relationship between management behaviors and safety outcomes in the 1990s (Stiles et al., 2018).

As a sub-system of leadership (Wu et al., 2016), SL is defined as "the process of interaction between leaders and followers, through which leaders could exert their influence on followers to achieve organizational safety goals under the circumstances of organizational and individual factors"(Wu et al., 2008). In short, SL can be regarded as the ability of leaders to inspire and motivate followers to safety goals (Donovan et al., 2018). In order to better measure SL, transformational leadership is constructed with four dimensions, including: idealized influence, inspirational motivation, intellectual stimulation and individualized consideration (Wu et al., 2016). Similarly, the dimensions of transactional leadership are composed of contingent reward and management-by-exception (Avolio et al., 1999), while those of LMX contain respect, obligation, and trust (Donovan et al., 2018). Meanwhile, some findings (Hofmann and Morgeson, 1999; Hofmann et al., 2003) demonstrated that LMX can influence how followers determine the roles with respect to organizational safety, and the followers who realized high quality relationships with their leaders were more inclined to raise safety concerns. Additionally, Kim and Gausdal (2017) identified some critical SL behaviors at all managerial levels to uncover the complete understanding of SL within the whole organization, involving lower, middle and top management.

In general, there are a large number of discussions of SL related to promoting safety performance. The assertion that SL positively affects safety compliance amongst employees was examined by numerous SL practices and observed safety effects (Pilbeam et al., 2016). Although substantial publications on different aspects of SL have been achieved, no bibliometric analysis is adopted to carry out the research associated with SL, resulting in a lack of comprehensive understanding in this field. The bibliometric tool is a quantitative statistical analysis method to provide an overview of extensive publications and grasp the current status in a specific research domain (Geng et al., 2017; Zhang et al., 2017; Soosaraei et al., 2018; Peng et al., 2018; Liao et al., 2019; Liu et al., 2020). The corresponding

conclusions are of great significance for researchers to determine the hot topics of study subjects, find suitable future research fields, and conduct cooperation with other countries or organizations (Tao et al., 2020).

Several software tools (Pan et al., 2018; Yang and Qiu, 2019) can be utilized to investigate SL from the viewpoint of bibliometric analysis, such as VOSviewer, CiteSpace, Bibexcel, CitNetExplorer, Network Workbench Tool, and HistCite, etc. As an efficient scientometric tool, VOSviewer was developed by van Eck and Waltman (2010) from Leiden University (The Netherlands). It is a freely available visualization software for presenting bibliometric maps. Some detailed information of VOSviewer tool is given in Van Eck and Waltman (2014). Accordingly, VOSviewer has been utilized by scholars in a variety of domains, such as hydrogen storage (He et al., 2019), process system failure and reliability (Tanjin Amin et al., 2019), supply chain of renewable energy (Azevedo et al., 2019), safety culture (van Nunen et al., 2018), construction and demolition waste management (Jin et al., 2019), etc. Although VOSviewer is popular in bibliometric analysis, no attempt has been made to apply it to understand SL research. Due to the increasing attention to the SL domain, it is necessary to summarize the current status and the evolution trend in SL. This paper aims to: 1) identify who are the most productive and influential researchers, institutions, and countries/regions in SL domain; 2) uncover what collaboration relationships exist in terms of countries, institutions, and authors; 3) explore what are the most influential journals and articles based on their citations and co-citation; 4) understand the current research topics and propose the future research direction in SL field. All the documents on SL are retrieved from the Web of Science (WoS) Core Collection database via VOSviewer. In terms of yearly outputs, authorship, countries, leading institutions, mainstream journals, citation performance, and keywords, the corresponding tables and figures are given for future scholars to grasp the overall status of SL studies and provide important ideas about the development trends.

2. Methodology

Bibliometrics analysis is a systematic method that can quantitatively assess the study status and trend of a specific subject (Wu et al., 2018; Mao et al., 2018; Soosaraei et al., 2018; Tao et al., 2020). As one of the most frequently applied software approaches in library and information science, VOSviewer is adopted to visualize the authorship, spatial distribution, and keywords in scientific literature related to SL, and provide a comprehensive picture on the future trends of knowledge, theories and research topics in this domain. The impact factor (IF) is regarded as the most common index for assessing the influence of a journal (Mao et al., 2018). Accordingly, the H-index refers to a certain period of time that h publications from an author, a journal, an institution, and a country, etc. have been cited at least h times (Mao et al., 2018; Yin et al., 2018). In the present work, the IF determined by Journal Citation Report in 2018 is adopted to evaluate the influence of the journals associated with SL publications. Meanwhile, the H-index is applied to confirm the impact of papers from diverse authors and countries/regions. The complex social relationship among different countries/regions, institutions, authors, and keywords can be uncovered using network analysis (Wu et al., 2018). Therefore, the collaboration, co-citation, and keywords co-occurrence were analyzed using social network.

This study was carried out on 9 September 2019. The term “safety leadership” was regarded as the search topic. It has been observed that the publication time of relevant documents were mainly recorded after 1999 in a preliminary study. Therefore, based on the Web of Science (WoS) Core Collection database, English documents related to SL in the titles, abstracts, and

keywords were extracted from 1999 to 2018. Also, the results irrelevant to SL research was screened manually. Microsoft Excel 2013 software was applied to analyze raw data obtained from WoS (CSV format). VOSviewer tool was adopted to visualize the knowledge maps of countries/territories, institutes, authors, co-citation, keywords co-occurrence. Furthermore, the current status, hot topics, and development trends in SL studies were analyzed. The whole research flowchart of this study is shown in Fig. 1.

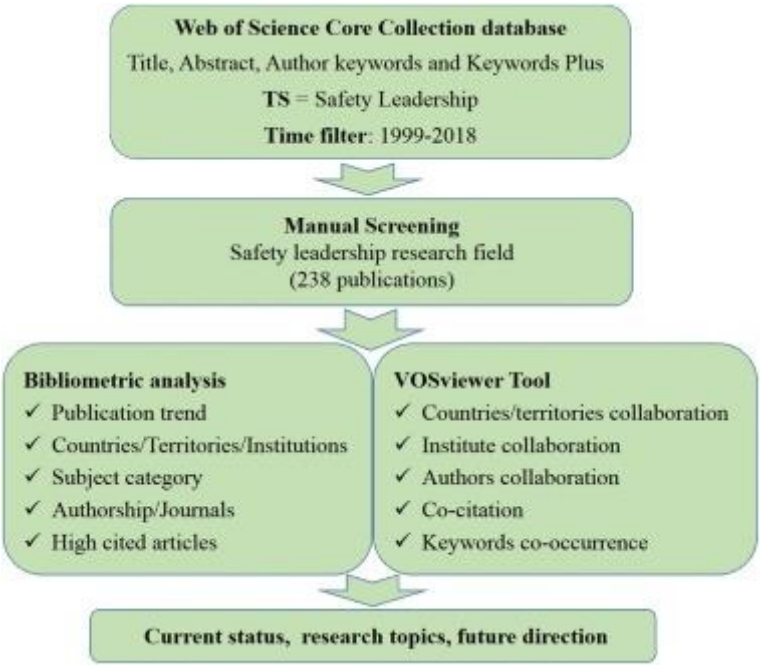

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Fig. 1. The flowchart of bibliometric analysis in SL research.

3. Results

3.1. Publication output and growth

A total of 238 publications associated with SL were retrieved via the Web of Science (WoS) Core Collection database. As shown in Table 1, there are 6 main document types in the publications. Journal articles (178) were the most frequently retrieved document type accounting for 74.8 % of the total number of publications. They were followed by Editorial material (23; 9.7 %), Meeting abstract (16, 6.7 %); Reviews (10; 4.2 %), Proceeding paper (3, 1.2 %), and Book review (1, 0.4 %). Additionally, some other types, such as News item, Letter, and Correction have low value in the bibliometrics analysis, so they are omitted in this study.

Table 1. Document type of SL during 1999–2018.

No.	Document types	Total Number of articles	Proportion (%)
1	Article	178	74.9 %
2	Editorial material	23	9.7 %

No.	Document types	Total Number of articles	Proportion (%)
3	Meeting abstract	16	6.7 %
4	Review	10	4.2 %
5	Proceeding paper	3	1.3%
6	Book review	1	0.4 %
7	others	7	2.9 %

As displayed in Fig. 2, the number of annual SL publications fluctuated from 1999 to 2018, with a remarkable rising phenomenon in 2008 due to the growing recognition of clinical leadership in patient safety. The number of articles per year was less than 5 before 2007, demonstrating an initial germination stage in SL research. During this period, there were very few papers related to SL studies while several high-quality articles has been published in this field. Zohar (2002a) investigated the relationships between safety climate and leadership, and presented a leadership-based intervention model to promote the subordinates' safety performance Zohar (2002b). Meanwhile, Barling et al (2002) developed and tested a safety-specific transformational leadership model to predict the occupational injuries. These explorations provided a strong basis for the subsequent SL studies. With the rapid development of technical conditions, organizational factors have been attached increasing importance in occupational safety, resulting in many scholars concentrate on SL research. In 2018 alone, 32 documents linked to SL were produced, whilst it can be found that the cumulative publication output of SL approximately follows an exponential growth. In general, the most recent decades witnessed a number of studies on examining the role of SL in promoting safety performance and outcomes, referring to a range of empirical practices, and safety performance and outcome measures (Donovan et al., 2018).

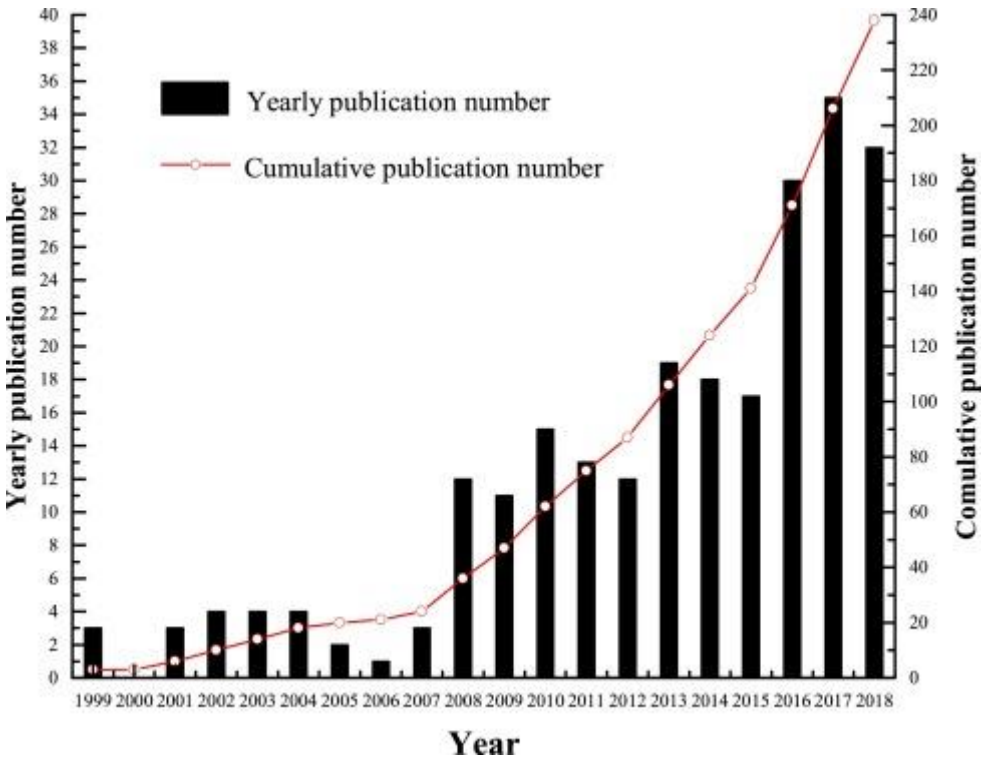

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Fig. 2. Number of SL publications and cumulative number of SL by year.

3.2. Spatial distribution of SL studies

According to the affiliations of authors, the SL contribution of different countries/territories and institutions was investigated. There was a large geographic range of academic documents on SL, covering 40 countries. As shown in Fig. 3, out of those 40, 20 countries originate from Europe, 10 from Asia, 3 from North America, 2 from South America (Trinidad Tobago, Brazil), 2 from Oceania (Australia, New Zealand), and 2 from Africa (Ghana, South Africa). There are 10 countries/territories (25%) publishing 10 or more documents, and 11 countries have produced only 1 publication in the SL domain. It is noteworthy that there are a total number of 93 articles from European countries. Table 2 lists the top ten most productive countries/regions ranked by the number of total publications with other information: single country, international collaborations, the first author, as well as the corresponding author. Obviously, the USA (78, 32.8 %) is the most productive country with the largest number of publications during this period, followed by England (24, 10.1 %), Canada (15, 6.3 %), China (14, 5.9 %), Australia (14, 5.9 %), Taiwan (12, 5.0 %), Switzerland (10, 4.0 %), Norway (9, 3.8 %), Scotland (9, 3.8 %), and Israel (8, 3.4 %). Similarly, the USA ranked first with regards to single country and international collaborative publications, as well as first author and corresponding author publications. With respect to the influence, the USA ranked first with a H-index up to 19, followed by England (14) and Canada (11).

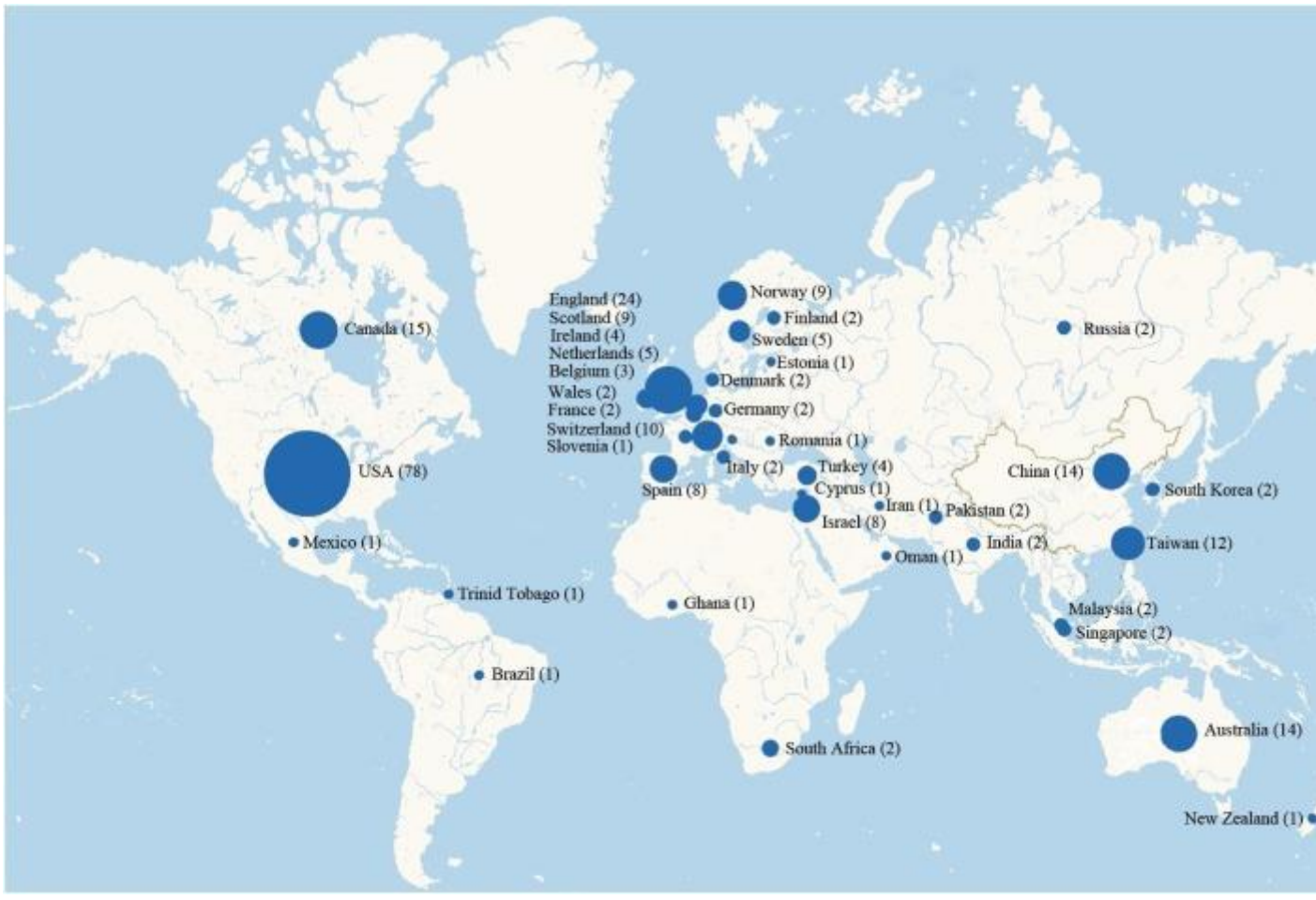

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Fig. 3. The number of SL publications distributed by countries/regions.

Table 2. The top 10 productive countries/regions of SL during 1999-2018.

Country/ regions	TP(%)	SP R(%)	CP R(%)	FP R(%)	RP R(%)	H-index(R)
USA	78(32.8 %)	1(25.6 %)	1(7.1 %)	1(29.4 %)	1(29.0 %)	19(1)
England	24(10.1 %)	2(6.7 %)	2(3.4 %)	2(7.6 %)	2(7.6 %)	14(2)
Canada	15(6.3 %)	3(4.6 %)	8(1.7 %)	3(5.5 %)	3(5.9 %)	11(3)
China	14(5.9 %)	6(3.4 %)	4(2.5 %)	3(5.5 %)	3(5.9 %)	6(7)
Australia	14(5.9 %)	5(3.8 %)	5(2.1 %)	5(3.8 %)	6(3.8 %)	7(5)
Taiwan	12(5.0 %)	4(4.2 %)	10(0.8 %)	5(4.6 %)	5(4.2 %)	6(7)
Switzerland	10(4.2 %)	10(1.3 %)	3(2.9 %)	10(1.7 %)	10(1.7 %)	8(4)
Norway	9(3.8 %)	8(1.7 %)	5(2.1 %)	7(3.4 %)	7(3.4 %)	6(7)
Scotland	9(3.8 %)	8(1.7 %)	5(2.1 %)	8(2.9 %)	9(2.9 %)	7(5)
Israel	8(3.4 %)	7(2.1 %)	9(1.3 %)	8(2.9 %)	7(3.4 %)	5(10)

TP: Total publications; SPR: Single country publication rank; CPR: International collaborative publication rank; FPR: First author publication rank; RPR: Corresponding author publication rank.

The cooperation relation among the countries/regions in the field of SL was also analyzed using social network analysis (see Fig. 4). The size of the circles represents the amount of related publications, and the thickness of links denotes the degree of international collaborations (Li et al., 2017). In other words, the larger the circle is, the more important the country is. Similarly, the thicker line indicates closer cooperation between countries/territories. As can be seen in Fig. 4, the USA (11 links) and England (7 links) play the predominant roles in SL studies. Meanwhile, the USA has close collaboration with Canada, England, Israel, and China. In general, more international collaboration in the SL domain should be promoted to share knowledge on SL in the future.

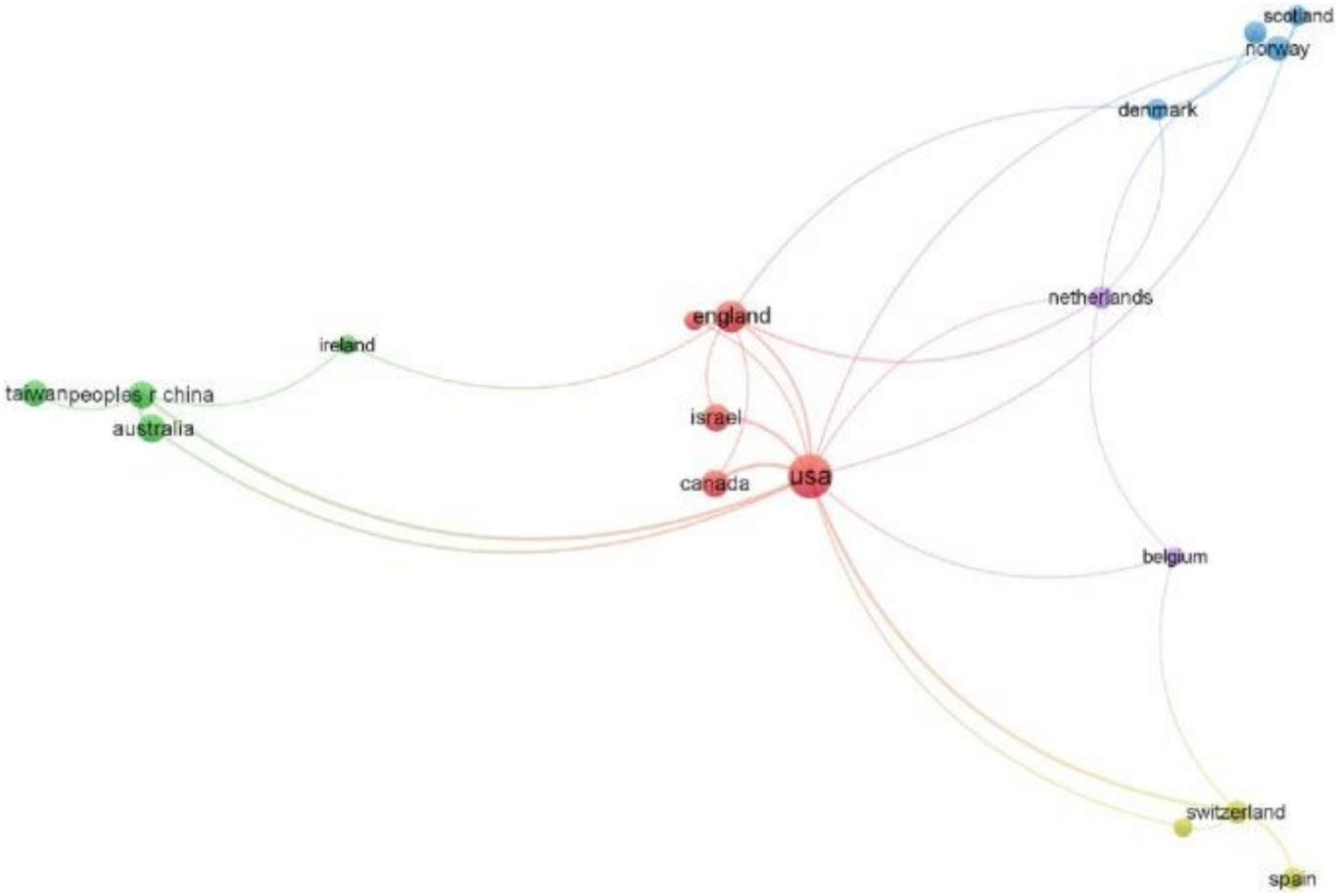

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Fig. 4. Cooperation network among countries/regions in SL research.

The devotion of 388 institutions was identified in the bibliometric analysis based on the authors' affiliation. The top ten institutions that contribute to the documents on SL are given in Table 3. It can be seen that the University of Aberdeen, Scotland (9, 3.8 %) is the most active institution related to SL over the world, followed by Monash University (Australia), Saint Marys University (Canada), University of Basel (Switzerland), and University of Texas System (USA) publishing six documents associated with SL, respectively. Additionally, University of Basel (Switzerland), University of Sheffield (UK), Duke University (USA), University of Toronto (Canada) published the most documents in respect to being single institute.

Table 3. The top 10 of most active institutions publishing on SL research.

Institutes	TP(%)	SP R	CP R	FP R	RP R
University of Aberdeen, Scotland	9(3.8 %)	1(2.1 %)	3(1.7 %)	1(3.4 %)	1(3.4 %)
Monash University, Australia	6(2.5 %)	2(0.8 %)	3(1.7 %)	2(2.5 %)	2(2.5 %)
Saint Marys University, Canada	6(2.5 %)	6(0.4 %)	2(2.1 %)	3(1.3 %)	5(1.3 %)
University of Basel, Switzerland	6(2.5 %)	10(0 %)	1(2.5 %)	8(0.4 %)	9(0.4 %)
University of Texas System, USA	6(2.5 %)	2(0.8 %)	3(1.7 %)	6(0.8 %)	6(0.8 %)

Institutes	TP(%)	SP R	CP R	FP R	RP R
Harvard University, USA	5(2.1 %)	2(0.8 %)	7(1.3 %)	4(2.1 %)	3(2.1 %)
University of Liverpool, England	5(2.1 %)	2(0.8 %)	7(1.3 %)	4(2.1 %)	3(2.1 %)
University of Sheffield, UK	5(1.30 %)	10(0 %)	7(1.3 %)	8(0.4 %)	6(0.8 %)
Duke University, USA	4(1.7 %)	10(0 %)	3(1.7 %)	6(0.8 %)	6(0.8 %)
University of Toronto, Canada	4(1.7 %)	10(0 %)	4(1.7 %)	10(0 %)	10(0 %)

TP: Total publications; SPR: Single institute publication rank; CPR: Inter-institutionally collaborative publication rank; FPR: First author publication rank; RPR: Corresponding author publication rank.

Fig. 5 presents the interactions through joint publications among diverse institutions with 28 organizations and 23 links. It can be observed that a majority of institutes (14) do not cooperate with others in publications. University of Texas System (6 links), University of Basel (5 links), and Saint Marys University (3 links) are the three main institutions in cooperation with others. Therefore, it can be concluded that there is a serious regional imbalance in SL research, and the institutional cooperation is at a very low level. However, in order to obtain the highest research quality, institutional cooperation should be encouraged to conduct knowledge exchange on SL among researchers (Aldieri et al., 2018; Yang et al., 2019).

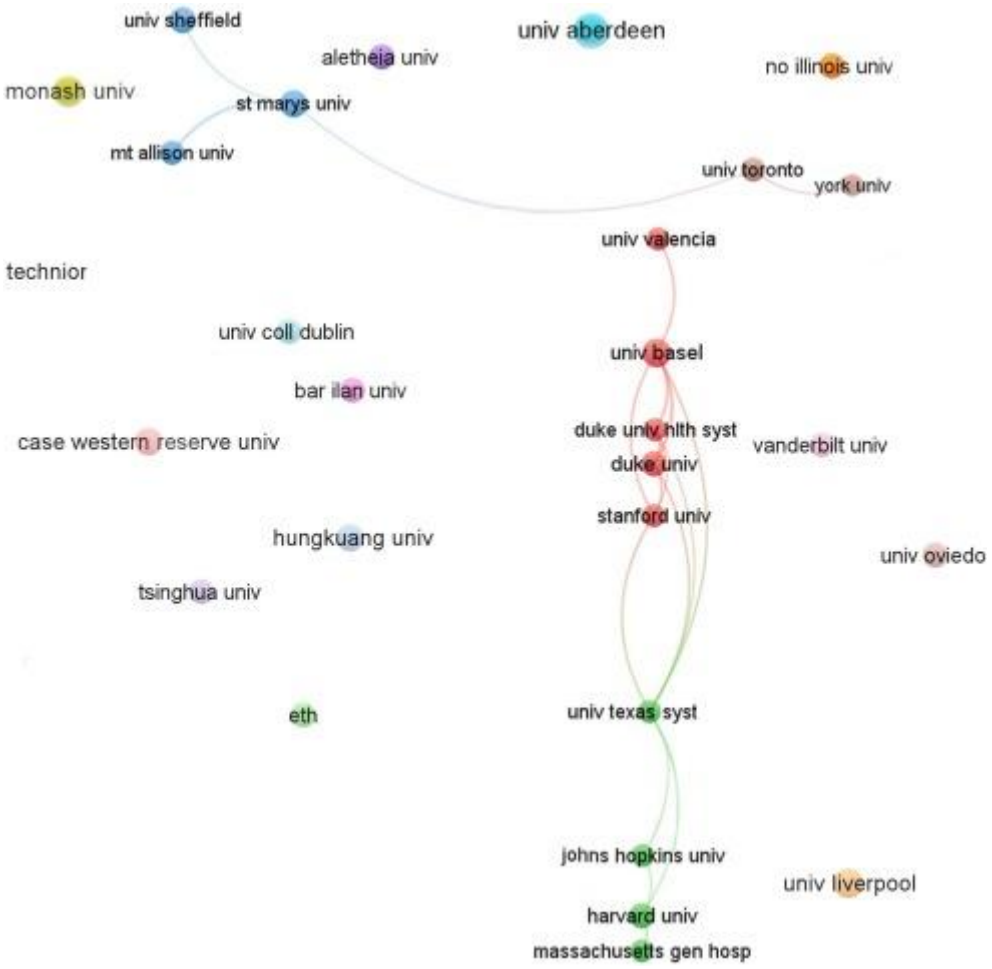

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Fig. 5. Cooperation network of institutions in SL research.

3.3. Journals analysis

There were 140 journals publishing SL research from 1999 to 2018. Table 4 presents some information of the top 10 most productive journals. The key journals in this field refer to *Safety Science* (23, 9.7 %), *International Journal of Psychology* (6, 2.5 %), *Journal of Nursing Management* (6, 2.5%), *Journal of Nursing Administration* (5, 2.1 %), *Journal of Occupational Health Psychology* (5, 2.1 %), and *Leadership Organization Development Journal* (5, 2.1 %), *Process Safety Progress* (5, 2.1 %), respectively. In the top-10 most active journals, the subject category *Engineering* and *Psychology* appears 4 and 3 times, respectively. Additionally, *Journal of Occupational Health Psychology*, *Safety Science*, *Journal of Nursing Management*, have high impact factor (IF) value in 2018of 5.128, 3.619, and 2.386, respectively.

Table 4. The top 10 of most active journals publishing on SL research.

No.	Journal title	Number of publications	Percentage (%)	Impact factor in 2018	Subject category of the journal
1	Safety Science	23	9.7 %	3.619	Engineering Operation research & management science
2	International Journal of Psychology	6	2.5 %	1.608	Psychology
3	Journal of Nursing Management	6	2.5 %	2.386	Business & Economics Nursing
4	Journal of Nursing Administration	5	2.1 %	1.206	Engineering Psychology
5	Journal of Occupational Health Psychology	5	2.1 %	5.128	Public, Environmental & Occupational Health Psychology
6	Leadership Organization Development Journal	5	2.1 %	1.462	Business & Economics
7	Process Safety Progress	5	2.1 %	0.885	Engineering
8	American Journal of Medical Quality	4	1.7 %	1.57	Health Care Sciences & Services
9	Nursing Economics	4	1.7 %	1.025	
10	Journal of Loss Prevention in the Process Industries	4	1.7 %	2.069	Engineering

3.4. Subject categories analysis

According to Web of Science, the 238 indexed documents on SL belong to 42 subject categories, covering a wide variety of disciplines. Fig. 6 demonstrates the subject categories containing more than 3 documents in the SL field. Apparently, the most related subject category on SL belongs to “Engineering” with 59 publications, followed by “Psychology” with 45 publications, “Business Economics” with 42 publications, “Nursing” with 38 publications, “Health Care Sciences Services” with 28 publications, “Operations Research Management Science” with 26 publications, and “Public Environmental Occupational Health” with 22 publications. Overall, SL study is obviously multidisciplinary, and the researchers range from social scientists to applied scientists.

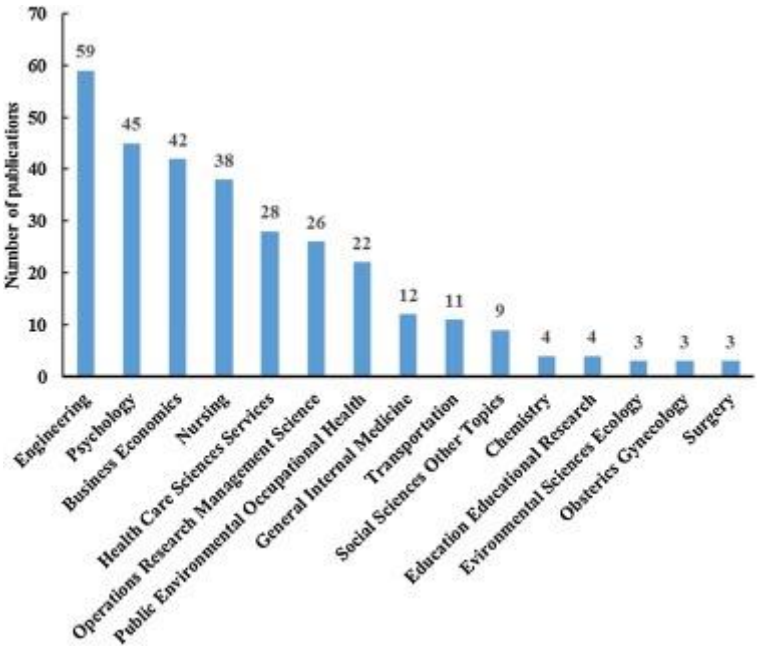

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Fig. 6. The subject categories with more than 3 publications on SL.

3.5. Authors and their cooperation

According to the author’s total number of documents, there were 622 authors publishing SL research. Table 5 presents the top-10 authors that have published the most papers on SL. Kelloway, from the Saint Marys University (Canada), is the author with the largest number of 6 SL articles, followed by Conchie, from the University of Liverpool (UK, 5 articles) and Flin, from the University of Aberdeen (UK, 5 articles). In addition, it can be observed that the average number of citations per publication ranges from 14.6 to 167.3. Furthermore, the relationship between authors in this field was obtained (see Fig. 7), with 27 items, 4 clusters, and 125 links. The number of publications is denoted by the size of the circles, while the cooperation can be represented by the line between two authors. The colors indicates “collaboration clusters”. It can be seen that the most predominate researchers in the cooperation network are Schwendimann and Sexton, with both a number of 21 links.

Table 5. The top 10 prolific authors on SL.

Author	Country/Institute	Number	Average citations per publication	H-index
Kelloway EX	Canada/ Saint Marys University	6	137.3	5
Conchie SM	UK/ University of Liverpool	5	38.8	5
Flin R	UK/University of Aberdeen	5	43.5	4
Eid J	UK/University of Aberdeen	4	20.3	3
Martinez-Corcoles M	Spain/University of Valencia	4	30.5	4
Mullen J	Canada/Mount Allison University	4	60.5	3
Schwendimann R	Switzerland/University of Basel	4	14.8	3
Wu TC	China/Hungkuang University	4	32	4
Zohar D	Israel/ Technion Israel Institute of Technology	4	167.3	3
Wu CL	China/Tsinghua University	3	14.8	3

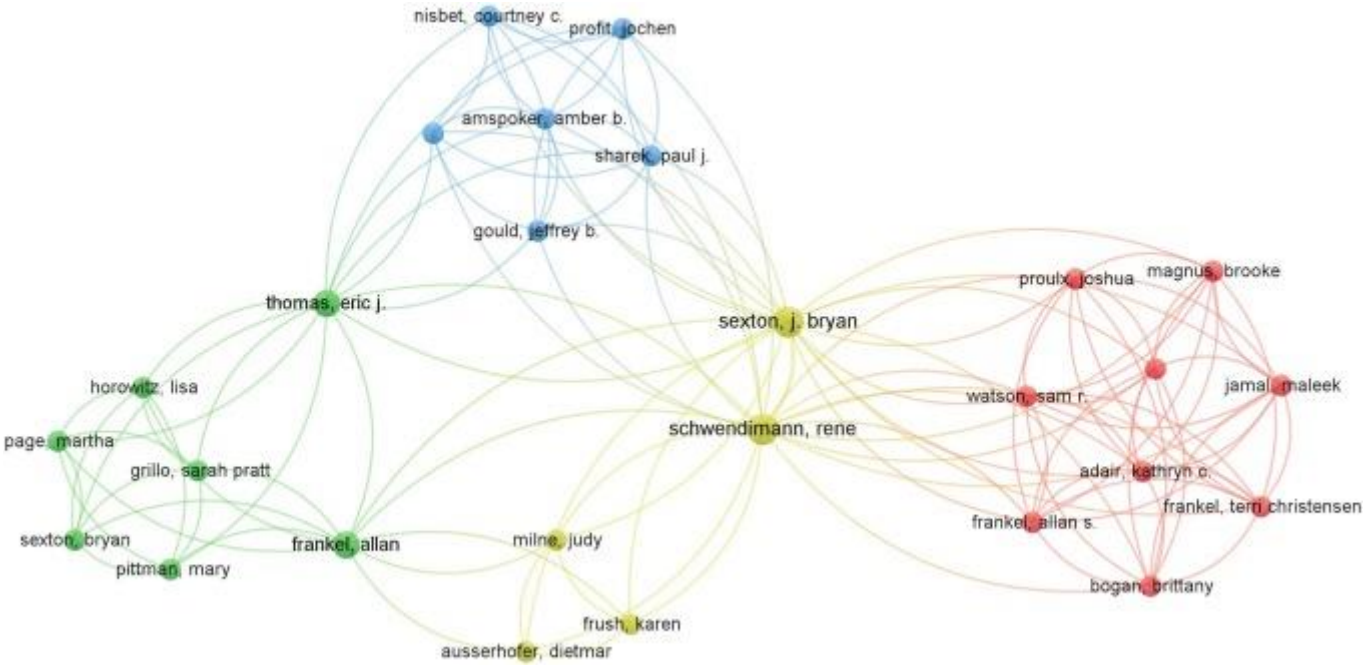

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Fig. 7. Authors cooperation network in SL research.

3.6. Citation and co-citation analysis

3.6.1. Citation analysis

The citation analysis indicates the number of times that SL documents have been cited by other publications in the Web of Science database. Table 6 shows the twenty most frequently cited SL publications with basic information: authors, journal title, total citations, and the country/institutions during 1999–2018. The most cited paper is authored by Barling et al. (2002) in *Journal of Applied Psychology*, with a total of 462 citations. The two articles

authored by Walumbwa and Schaubroeck (2009) and Zohar (2002), which are published by the *Journal of Applied Psychology* and the *Journal of Organization Behavior* respectively, are ranked as the second and third most highly cited articles, with 369 and 357 citations, respectively.

Table 6. The top 20 most frequently cited articles.

No.	Author	Journal	Country/Institute	Citations
1	Barling et al. (2002)	Journal of Applied Psychology	Canada/Queens University	462
2	Walumbwa and Schaubroeck (2009)	Journal of Applied Psychology	USA/Arizona State University	369
3	Zohar (2002a)	Journal of Organization Behavior	Israel/ Technion Israel Institute of Technology	357
4	Zohar (2002b)	Journal of Applied Psychology	Israel/ Technion Israel Institute of Technology	277
5	Kelloway et al. (2006)	Journal of Occupational Health Psychology	Canada/Saint Marys University	175
6	Clarke (2013)	Journal of Occupational and Organization Psychology	UK/University of Manchester	123
7	Mullen and Kelloway (2009)	Journal of Occupational and Organization Psychology	Canada/Mount Allison University	120
8	Flin and Yule (2004)	Quality & Safety in Health Care	UK/University of Aberdeen	120
9	O'Dea and Flin (2001)	Safety Science	UK/University of Aberdeen	120
10	Vogus and Sutcliffe(2007)	Medical Care	USA/Vanderbilt University	110
11	Carmeli et al. (2010)	Creativity Research Journal	USA/University of Alabama Huntsville	107
12	Künzle et al. (2010)	Journal of Experimental Psychology: Applied	Switzerland/ ETH Zurich	94
13	Wu et al. (2008a)	Journal of Loss Prevention in the Process Industries	China/National Cheng Kung University	92
14	McFadden et al. (2009)	Journal of Operations Management	USA/Northern Illinois University	84
15	Lu et al. (2010)	Safety Science	China/National Cheng Kung University	74
16	Frankel et al. (2008)	Health Services Research	USA/Harvard University	70
17	Ruchlin et al. (2004)	Journal of Healthcare Management	USA/Cornell University	70
18	de Koster et al. (2011)	Journal of Operations Management	Netherlands/ Erasmus University	69

No.	Author	Journal	Country/Institute	Citations
19	Martínez-Córcoles, et al. (2011)	Safety Science	Spain/University of Valencia	62
20	Kapp (2012)	Safety Science	USA/University of Wisconsin	61

In comparison with the content of the twenty most frequently cited publications, the researchers focused on the examination of the effects of specific leadership models on employee's safety performance. Clarke (2013) found that active transactional leadership plays an important role in guaranteeing obedience by rules and regulations, while transformational leadership for safety is mainly related to inspiring employee engagement in safety. In addition, the USA is best denoted as country of the first author with seven publications, followed by Canada with three publications. Zohar (2002a, 2002b) from Israel appears twice as the first author in the list. The journal *Safety Science* is best represented with four articles, followed by *Journal of Applied Psychology* with three publications. In addition, five of the publications are related to "transformational and transactional leadership" by examining the content of the twenty most frequently cited articles.

3.6.2. Co-citation analysis

Based on the citations, co-citation analysis aims to identify the relationship between a pair of papers cited together by other publications (Geng et al., 2017; Yang et al., 2019). There are three types of co-citation analysis, referring to references, journal sources, and authors (Azevedo et al., 2019). Fig. 8 presents the co-citation map of references cited more than 10 times by SL publications. A paper is indicated on the map by a node and the corresponding size demonstrates the total citation times of this article. A bigger node indicates a larger citations number. In general, there are 6536 references cited by the 238 indexed documents on SL. It is clear that 70 references in the network are classified into four clusters, indicating different research themes on SL. According to the titles of all individual papers in the four clusters, the red cluster concentrates on SL models. The article authored by Barling et al. (2002) has the highest number of links (19) and citations (57). The green cluster focuses on safety climate, in which the publication authored by Hofmann (1999) is the core article (links, 65; citations, 40). The yellow cluster emphasizes on the SL effects, the paper authored by Kelloway (2006), is the most influential document (links, 63; citations, 39). Regarding the blue cluster, it is associated with SL theoretical review and the paper authored by Edmondson (1999) is the most important publication with 36 links and 29 citations.

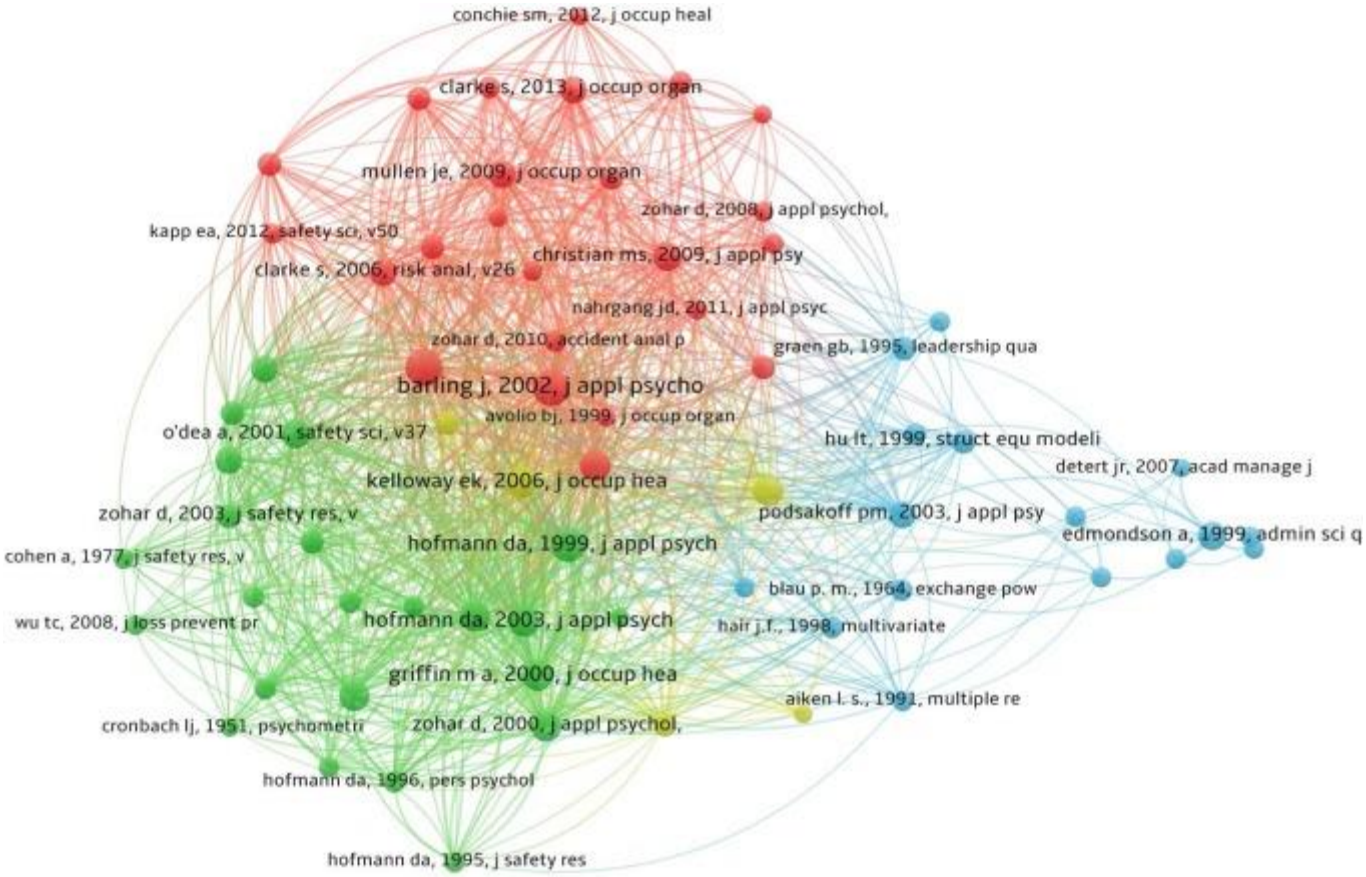

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Fig. 8. Reference co-citation map.

The author co-citation analysis is used to understand scholars' activities in a specific field (Backhaus et al., 2011). Fig. 9 shows the author co-citation network using the first author with a threshold of 10 citations. In general, there are 4530 authors cited by the 238 retrieved publications, and 113authors were cited 10 times or more. The most frequently-cited author is Zohar (Israel Institute of Technology), followed by Bass, from State University of New York, and Barling, from Saint Mary's University. Similarly, four distinct clusters can be found according to the colors. The green cluster mainly includes Zohar (112 links), Flin (106 links), and Mearns (100 links). The yellow cluster mainly contains Bass (110 links), Barling (108 links), and Clark (108 links). The red cluster is mainly composed of Yukl (105 links), Walumbwa (87 links), and Edmondson (83 links). In addition, the blue cluster mainly covers Avolio (110 links), Reason (99 links), and Sexton (62 links).

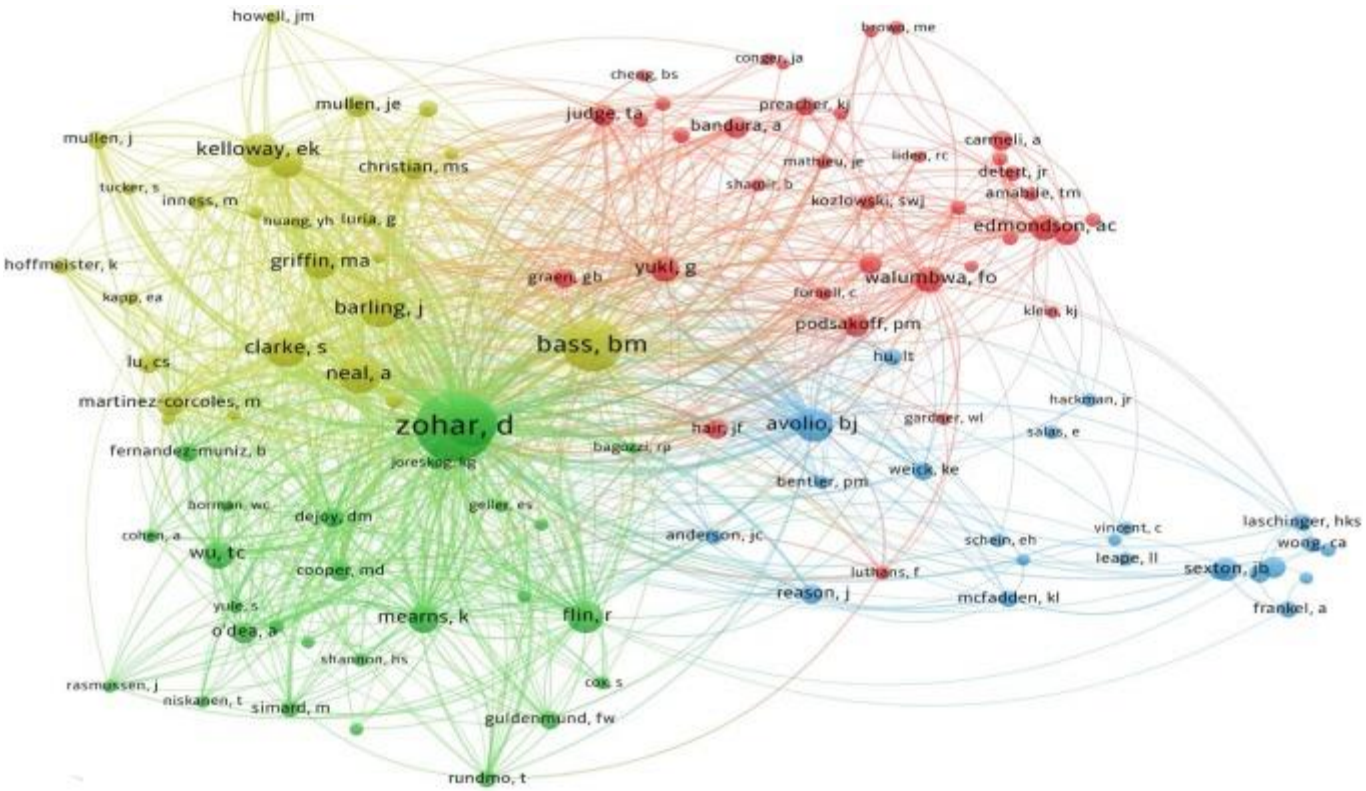

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Fig. 9. Author co-citation map on SL.

The co-citation of journals happens when two articles from different journals are cited together by the same publication of another journal (Merigó et al., 2019). In total, there are 2808 journals cited by 238 retrieved documents on SL. Fig. 10 indicates the co-citation map of journals with a threshold of 30 citations. Obviously, *Journal of Applied Psychology* was the most influential journal, publishing 3 papers with a total of 1108 citations. 35 journals in the network can be divided into three clusters. The red cluster mainly concentrates on the journals related to management, such as *Journal of Applied Psychology* (34 links), *The Leadership Quarterly*, and *Academy of Management Journal*. The green cluster focuses on the journals associated with occupational health and safety, including *Safety Science* (34 links), *Journal of Safety Research*, *Accident Analysis and Prevention*, and *Journal of Occupational Health Psychology*. Meanwhile, the blue cluster emphasizes on the journals of health care, such as *Quality & Safety in Health Care* (37 links), and *BMC Health Services Research*.

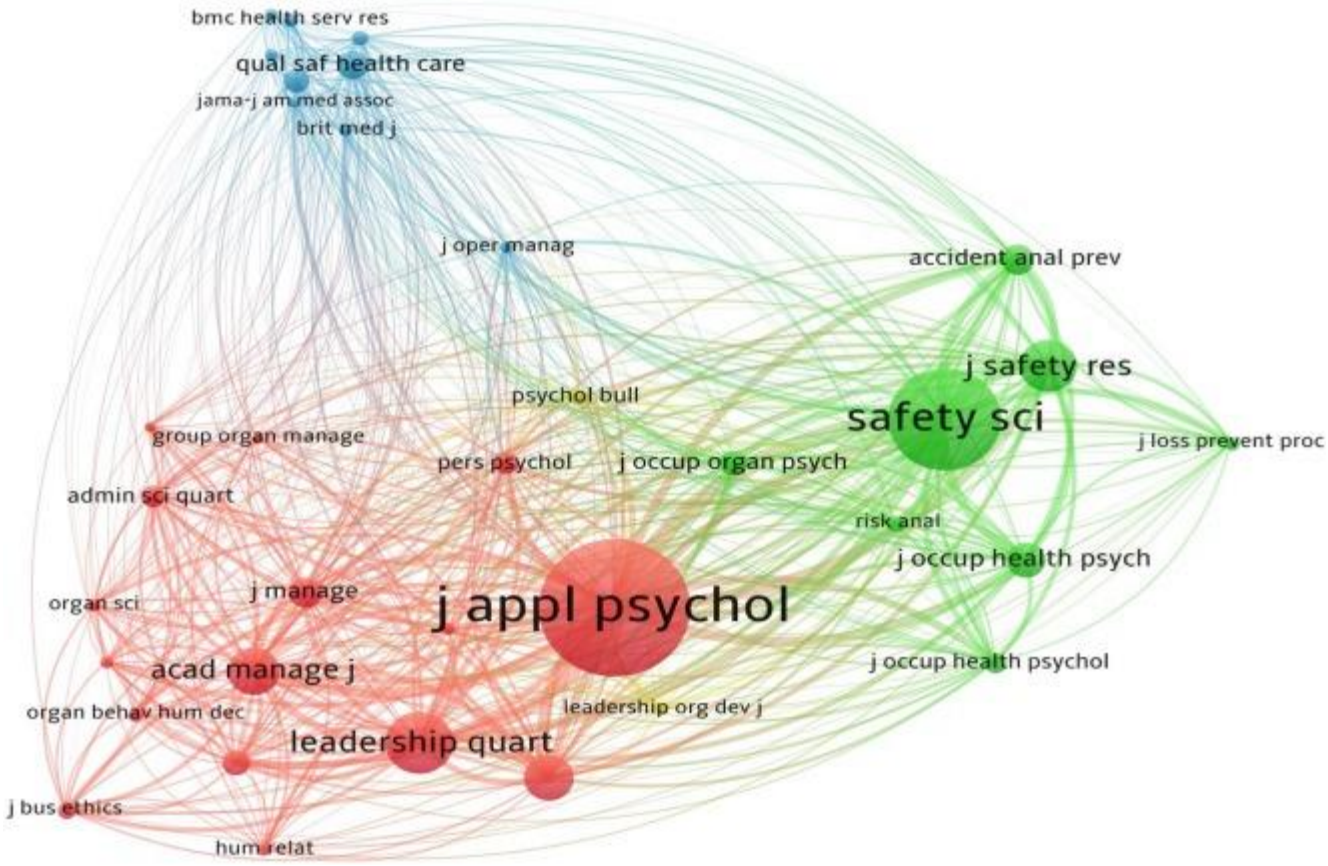

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Fig. 10. Journal co-citation map.

3.7. Keywords analysis

The core content of the papers can be represented by keywords, so the analysis of keywords aims to grasp significant research topics in SL research domain. Also, a network can be obtained by applying keyword co-occurrence analysis based on VOSviewer tool. Fig. 11 indicates the overview of the keyword co-occurrence map with 166 nodes. A node denotes one key term derived from the publications related to SL. The size of each node represents the co-occurrence frequencies of the related keywords (Li et al., 2017). It is clear that four distinct clusters can be found in Fig. 11. The red cluster is concerned with empiric supports of leadership on safety performance, covering safety performance, safety behavior, safety attitudes, structural equation model, mediating role, moderating role. It can be concluded that a structural equation model based method is frequently adopted to identify the roles of leadership in safety performance (Zhang et al., 2018). The blue cluster focuses mainly on various leadership styles applied in safety, including transformational leadership, transactional leadership, member exchange, and authentic leadership. The green cluster presents keywords associated with the specific application of SL in health care: patient safety, health-care, hospitals, health, nurses, etc. Finally, the yellow cluster as the smallest group, concentrates on the correlation between SL and safety climate.

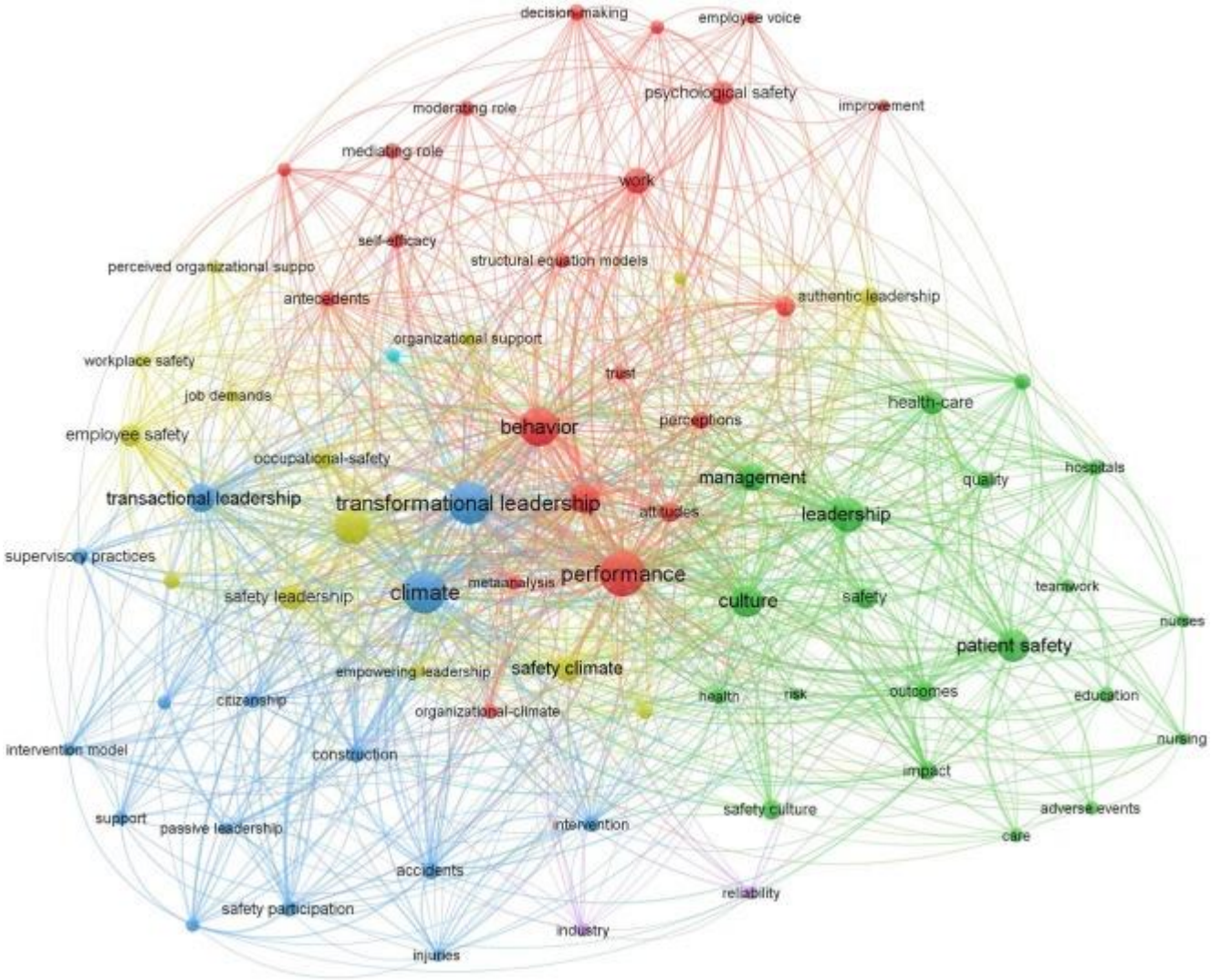

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Fig. 11. Keywords co-occurrence analysis of SL publications.

Moreover, Table 7 presents the top 40 terms in SL studies, which take up more than 80% of all keyword frequencies. It is apparent that “performance” is the most frequently used keyword with 64 times, followed by “climate (59)”, “transformational leadership (54)”, and “behavior (49)”. At the same time, “member exchange (37)”, “Patient safety (33)”, “culture (32)”, and “model (28)” are also specific research hotspots in the SL research field. Among the top 40 keywords, four of them are associated with leadership types. SL is a sub-system of leadership, thus a large number of safety studies concentrate on the full range leadership model (Wu et al., 2016). Accordingly, employees’ safety performance refers to safety participation and safety compliance while leaders’ safety behaviors are related to safety inspiring, safety monitoring, and safety learning. In addition, a mediating (moderating) role refers to “perceived safety climate partially mediating the effect of leadership on safety participation” (Clarke, 2013). Considering the central role of a leader in organizational safety, leader training is regarded as a promising intervention in safety management (Mullen and Kelloway, 2009; von Thiele Schwarz et al., 2016).

Table 7. Top-40 keywords in SL research from 1999-2018.

Number	Keyword	Frequency	Number	Keyword	Frequency
1	Performance	64	21	Outcomes	12
2	Climate	59	22	Attitudes	12
3	Transformational leadership	54	23	Safety culture	12
4	Behavior	49	24	Impact	11
5	Leadership	38	25	Accidents	10
6	Member exchange	37	26	Perceptions	10
7	Patient safety	33	27	Safety participation	9
8	Culture	32	28	Construction	9
9	Model	28	29	Job-satisfaction	9
10	Transactional leadership	25	30	Supervisory practices	9
11	Safety climate	23	31	Mediating role	9
12	Management	23	32	Organizational support	8
13	Work	21	33	Hospitals	8
14	Safety Leadership	20	34	Intervention	8
15	Psychological safety	17	35	Self-efficacy	8
16	Health-care	17	36	Decision-making	8
17	Employee safety	16	37	Health	8
18	Occupational-safety	13	38	Education	8
19	Authentic leadership	13	39	Moderating role	7
20	Organizations	13	40	Meta-anlysis	7

For understanding the research theme on SL in the most recent 3 years, Fig. 12 demonstrates the density view of hot terms on SL research from 2016 to 2018. Obviously, the influence of various leadership styles on safety performance is always a research topic in the SL domain. A majority of present SL studies concentrated on common leadership theories (Kim and Gausdal, 2017; Donovan et al., 2018; Wu et al., 2011), such as transformational leadership, transactional leadership, empowering leadership, leader-member exchange (LMX), authentic leadership, etc. Donovan et al. (2018) summarized the five SL models in terms of leadership styles, attributes, and behaviors. Whilst there are some new terms, such as psychological safety, supervisory practices, ethical leadership, charismatic leadership, leadership behavior, system thinking, construction, and nuclear power plant.

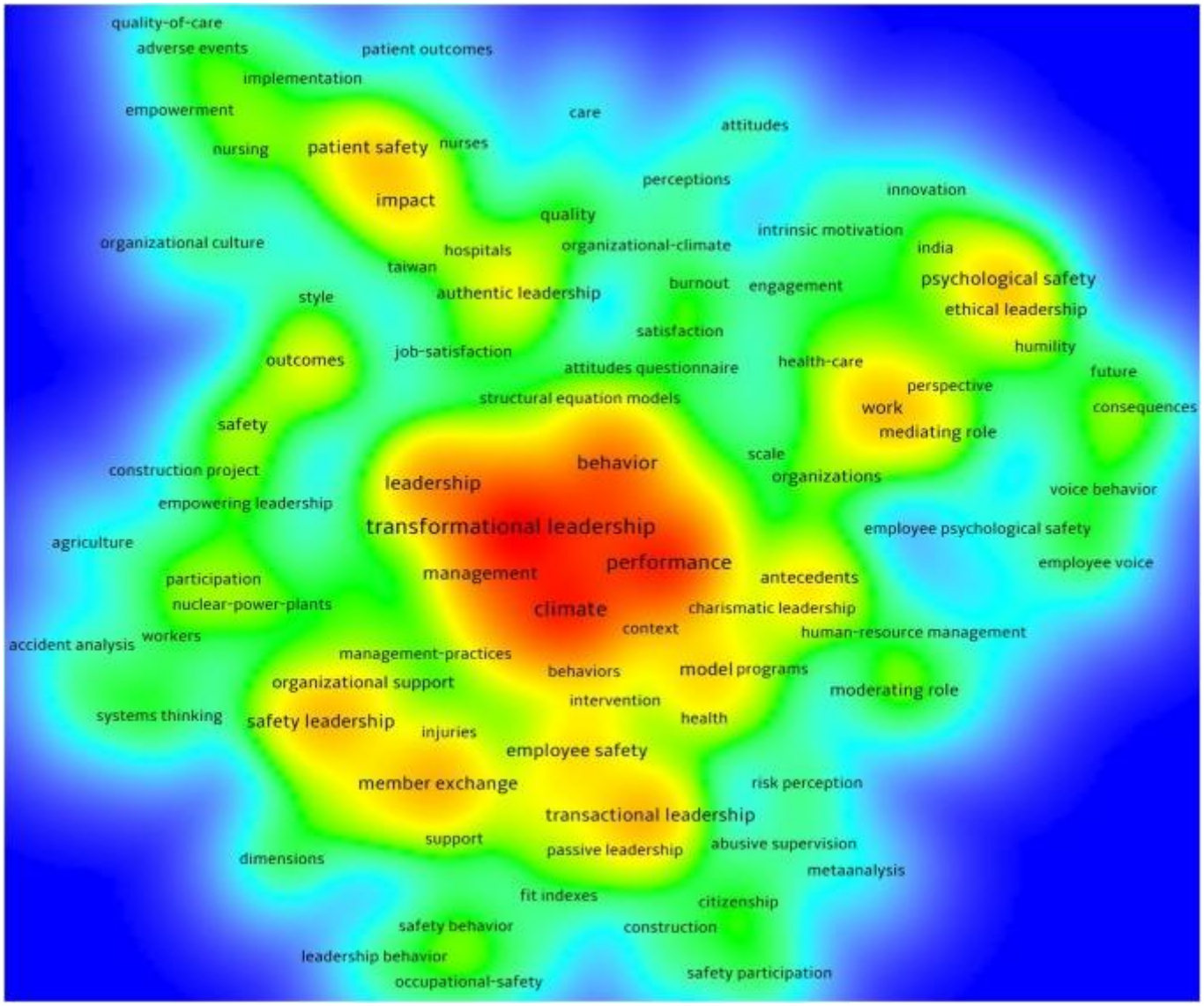

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Fig. 12. Hot keywords of the SL studies between 2016 and 2018.

4. Discussion

It has been recognized that safety performance can be promoted by leaders' commitment to safety, and poor SL has a negative influence on the organization's safety culture (Stiles et al., 2018). This paper aims to carry out a systematic and quantitative evaluation of the documents on SL based on the Web of Science Core Collection database. This is the first study to focus on a bibliometric analysis of SL throughout its history, and the network visualization maps for collaboration, co-citation, and keywords co-occurrence have never been utilized in the SL domain. Overall, SL research has attracted a growing attention in recent ten years. Although there was a large geographic range of academic documents on SL, the USA is the most predominant country, followed by UK and Canada. Another feature of spatial distribution is that few studies originated from developing nations, such as India, South America, Middle Eastern, and African countries. Similarly, authors from USA played a primary role in

international co-authorship, followed by UK and the Netherlands. In contrast, academic correlations were still relatively inadequate in Asian countries due to language differences. With respect to institutional collaborations, most of the institutes conduct SL research independently, while a few organizations collaborate with a small group of patterns, resulting in a serious regional imbalance in SL studies. Regarding the journal analysis, SL documents mainly originated from *Safety Science*, *International Journal of Psychology*, and *Journal of Nursing Management*. This is because the SL topic is suitable for the aim of these journals, which are introduced on the respective websites. Concerning citation analysis, the most frequently cited article refers to a model linking safety-specific transformational leadership to occupational injuries, providing a new idea for SL researchers. In general, a majority of the most frequently cited documents focus on the empirical studies between SL and safety performance. Furthermore, SL study is multidisciplinary, referring to "Engineering", "Psychology", "Business Economics", and "Nursing. It is well known that collaboration and exchanges are of great importance in scientific research. The scholars from various science fields should be encouraged to conduct knowledge communication on SL topics. In terms of research theme in the SL domain, "transformational leadership", "performance", "behavior", and "climate" are obviously by far the most utilized keywords. In other words, a large number of safety publications concentrate on the full range leadership model (Wu et al., 2016). Similarly, extensive studies aim to examine the impact of specific leader behavior on employee's safety performance (Griffin and Hu, 2013). Moreover, a body of empirical findings aim to support the correlation between different leadership styles and safety performance (Martínez-Córcoles and Stephanou, 2017). The current SL studies have emphasized the leader styles instead of the practices which construct leadership (Besikçi, 2019), and fail to explain the impact of context on the practices (Pilbeam et al., 2016).

Many studies applied a Multi-factor Leadership Questionnaire to examine SL behavior (Pilbeam et al., 2016), resulting in heavy reliance on some particular items. Consequently, it is critical to integrate some innovative methods in SL research. In order to test the effect of SL on safety performance, the future studies should provide a large sample size and conduct multi-level study to obtain significant results (Martínez-Córcoles et al., 2011). Considering the conceptual and methodological limitations in SL study, system-thinking is effective to understand SL across work systems (Goode et al., 2014; Donovan et al., 2018). Due to some measurement errors in previous path analysis, structural equation modeling is also recommended to uncover the potential correlation among SL, safety climate and safety performance (Wu et al., 2008a). According to Wu et al (2008b), it can be concluded that SL is influenced by a variety of factors, such as organization size, location, ownership, employee's gender, accident experience, safety training, etc. Therefore, the interaction effects of these elements on SL should be understood in the future study. Combining the organizational and individual factors Wu (2008), it is necessary to conduct a comprehensive evaluation on SL and explore corresponding SL interventions. Similarly, it is of great significance to examine the leader characteristics which can drive SL, so the research results can be helpful in the choice and development of potential safety leaders (de Koster et al., 2011). Given the importance of teamwork and communication in safety management, the attention of SL research in recent years mainly focuses on health-care, nuclear power plant, construction, mining, petrochemical industries, air traffic control, and military operations. In today's information era, future researchers should explore the practical application of SL in others fields, such as intelligent manufacturing, logistics transportation, fishing, emergency sector, education industries, etc. With the rapid development of human society, occupational safety has become an increasing concern in all walks of life. SL is regarded as the key to enhancing organization safety performance (Zhang et al., 2018), particularly for those developing

countries where industrial infrastructure is faced with serious safety challenges. Therefore, future research in SL field should be stimulated in the underdeveloped regions, such as parts of Africa, the Middle East, and South America. As an effective approach for visualizing discipline knowledge, the bibliometric tool is proposed to understand the development trend on SL studies periodically in this information era. Furthermore, there are several software tools for bibliometric analysis (Pan et al., 2018; Yang and Qiu, 2019), such as VOSViewer, CiteSpace, CitNetExplorer, HistCite, Bibexcel, and Network Workbench Tool, etc. It is interesting for future researchers to conduct a comparative study of SL scientific documents with different tools.

The same as a lot of research, some limitations exist in the present work. The data utilized in this study were extracted only from WoS Core Collection database, which is incompatible with other databases like Compendex and Scopus (Yang et al., 2020), resulting in missing some publications associated with SL. Moreover, the SL articles in non-English languages may not be contained in the WoS database and analyzed. To the best of our knowledge, there are at least 40 papers on SL in the Chinese National Knowledge Infrastructure database, which are excluded in the bibliometric analysis. Due to its dynamic performance, the citation over time gives previous papers advantages over the latest publications, leading to a bias in the explanation of this index (Boudry et al., 2018). In addition, the analysis of the four clusters on the keywords co-occurrence map is non-quantitative and accordingly subjective. Considering the extensive publications extracted by manual analysis, some irrelevant papers may have been involved but the related articles may have been ignored.

5. Conclusions

An investigation of the documents on SL was presented with the information involving document types, countries/regions, institutions, journals, authorship, citation, and keywords. In general, 238 documents on SL were indexed, covering 622 authors, 140 journals, 40 countries, and 388 institutes between 1999 and 2018. The studies related to SL have been growing from 3 in 1999 to 126 in 2018. The USA, UK, and Canada lead scientific production on SL research, while further collaboration among different countries/organizations should be strengthened in the future. Kelloway, Conchie, and Flin are the most active researchers in this field. *Safety Science*, *International Journal of Psychology*, and *Journal of Nursing Management* are the major sources of SL publications. In addition, the University of Aberdeen (England) is the most productive research institute. Due to the multidisciplinary characteristics in SL research, it is necessary to encourage scholars from different science fields to conduct knowledge exchange on SL topics. According to the frequency of keywords, the hot topics in SL research domain concentrate on empiric supports of leadership on safety performance, various leadership styles applied in safety, specific applications of SL in health care, and the correlation between SL and safety climate. Similarly, there are new research topics appearing in recent years, concentrating on *psychological safety*, *authentic leadership*, *ethical leadership*, *charismatic leadership*, *empowering leadership*, *leadership behavior*, and *system thinking*. The present study provides a holistic map of SL studies, and the corresponding results can propose some significant information for future researchers to better understand the state-of-the-art of research themes associated with SL.

Declaration of Competing Interest

We declare that we do not have any commercial or associative interest that represents a conflict of interest in connection with the work submitted.

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Appendix A. Supplementary data

The following is Supplementary data to this article:

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