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Current Status and Future Directions of Construction Safety Climate: Visual Analysis Based on WOS Database

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Abstract: Construction safety climate (CSC) has become an important part of the construction safety research field in recent years. This paper analyzes the current research status, hot spots, and trends of CSC by sorting 531 articles in the Web of Science (WOS) database from 2017–2022 through the visualization software VOSviewer. The study shows that (1) China has made significant contributions to CSC research, with Chan, A.P.C. being the most published and cited scholars in recent years, respectively, laying the foundation for CSC; (2) the hotspots of CSC include two main directions, namely research on CSC dimensions and evaluation systems, and the combination with cross-cutting themes (such as safety culture, safety performance, and safety behavior); (3) the research on CSC and safety behavior has become one of the most prominent research directions, mainly divided into two aspects, namely workers' causes and external causes; (4) a warning system of safety behavior for construction workers through CSC is still worthy of exploration. The results of this study could help scholars clarify the research lineage and current situation in this field and to grasp future research directions.

Keywords: construction safety climate; safety performance; safety culture; safety behavior; bibliometric analysis

Citation: Liu, X.; Xue, Z.; Ding, Z.; Chen, S. Current Status and Future Directions of Construction Safety Climate: Visual Analysis Based on WOS Database. *Sustainability* **2023**, *15*, 3911. https://doi.org/10.3390/su15053911

Academic Editors: Rui Pang, Yantao Zhu, Binghan Xue and Xiang Yu

Received: 8 January 2023
Revised: 18 February 2023
Accepted: 19 February 2023
Published: 21 February 2023

1. Introduction

The construction industry is an important economic pillar industry all over the world [1,2]. However, it is noted that the construction industry is often viewed as a high-risk field, where safety conditions have always been a concern [3]. In order to explore ways to ensure safety in the construction industry, studies had explored and derived insights about how to reduce construction accidents over the past decades, including construction safety climate (CSC), safety performance (SP), and safety culture [4,5].

This research focuses primarily on research related to CSC. "Safety Climate" was first put forward by the scholar Zohar in 1980. According to the concept of organizational climate and his research on Israeli manufacturing workers, the safety climate was defined as a common understanding of a dangerous working environment [6]. Since the introduction of the 'Safety Climate' in 1980, many scholars have conducted a lot of research in the field. Niskanen et al. identified safety climate as a specific organizational attribute that can be perceived by workers, including an organization's management systems and policies for employees [7]. Coyle considered safety climate as an objective measure and an expression of employee's psychological perception reflecting employees' attitudes towards occupational health [8]. Many studies found that CSC is very important to construction projects, as CSC will affect the safety of construction projects. Since the term "CSC" was introduced, there has been a great deal of research on CSC [9]. Researchers have extensively examined the relationship between safety climate, SP, and safety culture, and found that they are positively correlated [10,11]. Furthermore, there has been research on how to assess safety climate and analyze the influencing factors within safety climate [3,12,13]. Since 2019, some

scholars have combined workers and project participants to analyze their role in CSC, promoting the development of the field of CSC [10,14].

However, it is found that, in recent years, scholars have focused on the influence of workers and worker behavior on CSC while neglecting research on the dimensions of CSC itself and its relationship with horizontal disciplines, and relevant CSC research has not been updated. Thus, CSC research may deviate from its intended purpose and direction over the course of its development [15,16]. Therefore, this study intended to study the development trend of CSC research in recent years by applying the scientometric method, scientific mapping method, and visualization software, and to quantitatively analyze the attributes, such as publication year, keywords, and journals between 2017 and 2022. Meanwhile, based on the results of quantitative analysis, the mainstream research topics in safety climate and the limitations and gaps of the existing research in the field of CSC will be discussed, and future research trends in constructive directions can be proposed.

The present study is structured as follows: (1) applying the scientometric method and VOSviewer software to quantitatively analyze research relevant to safety climate; (2) analyzing the mainstream research topics in the field of safety climate; (3) discussing the limitations of existing research in the field of CSC; (4) proposing future research trends in the field of safety climate guidance.

2. Methods

This study adopts scientific cartography methods of combining bibliometric analysis and scientific econometric analysis to investigate research in the area of CSC. The procedure is shown in Figure 1.

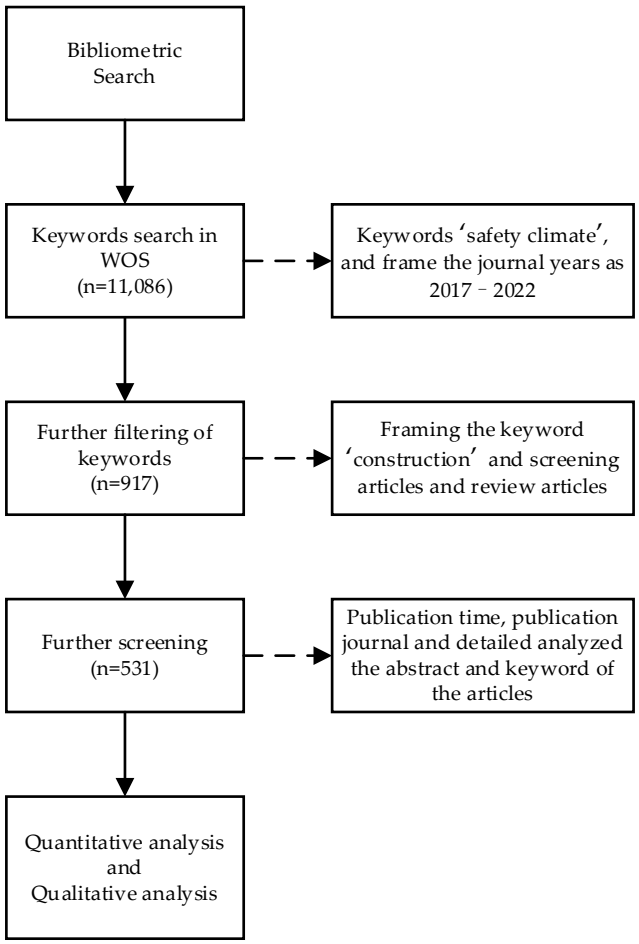

Figure 1. Article screening process.

2.1. Bibliometric Search

A bibliometric search in WOS was the first step in this process. We put in the keyword "safety climate" and the year of publication "2017–2022" to sort out published papers from the WOS database [17]. After the sorting work, 11,086 documents were identified.

To further narrow down the sorted results, the keyword "construction" was put in, resulting in 920 pieces of literature. Following this step, the types were then framed as papers and reviews, excluding conference publications, resulting in 917 papers from the literature.

Next, the abstracts and keywords of the remaining 917 papers were analyzed in detail according to Figure 1. Although some studies mentioned "construction" and "safety climate", the focus of these studies was not on safety issues in the construction industry, and, as such, they are not considered in this study. Studies [18,19] that focused on assessing the relationship between heat exposure and occupational trauma in construction workers were also excluded. Moreover, the scope of this paper should pertain to construction workers, construction risks, safety culture, and SP. Therefore, relevant studies that focus only on structural and material safety in construction without considering CSC were also excluded.

After several rounds of screening, 531 journal papers and review articles were eventually selected for subsequent quantitative and qualitative analysis.

2.2. Quantitative Analysis

The obtained 531 papers were subjected to scientific econometric analysis via the literature visualization software VOSviewer [20]. VOSviewer is used to visualize the author's collaboration network and keyword co-occurrence network [17], to study changes in themes over time, and to analyze the evolution of research themes. Furthermore, the scientometrics analysis method can be applied to analyze researchers' academic activities and socio-organizational structures [21]. Furthermore, in order to generate the visual analysis network, this paper quantitatively analyzes the keywords and authors of CSC research through VOSviewer.

2.3. Qualitative Analysis

Qualitative analysis is intended to analyze mainstream research topics in the CSC field, the current research status, and to identify gaps and limitations, providing information and directions for future research.

3. Result of Quantitative Analysis

In this section, quantitative analysis of screened papers in the field of CSC research is presented in five parts: year and country/region analysis, keyword analysis, journal analysis, scholar analysis, and institutional analysis.

3.1. Year and Country/Area Analysis

First, the year of the publications was analyzed. Figure 2 shows the distribution of article publication years between 2017 and 2022. Since 2017, an increasing number of relevant papers in the field of CSC have been published, and the number of publications is also increasing annually. In 2022, 129 relevant papers were published. It can be anticipated that more publications in CSC-related fields will be released in the near future.

In addition to the number of documents issued per year, the number of documents issued is divided and summarized according to the country/region of the author. Figure 3 shows which countries/regions have published papers on CSC between 2017 and 2022. It is evident that the People's Republic of China (PRC), the United States, Australia, England, and Iran are the top five countries or regions in terms of the total number of documents. Among them, PRC, the United States, and Australia have weighed more publications than other countries and regions. In addition, the PRC ranked first with 211 relevant papers, followed by the United States and Australia with 91 and 83 papers, respectively. It is found

that these regions have relatively better economic development and have a high focus on construction safety.

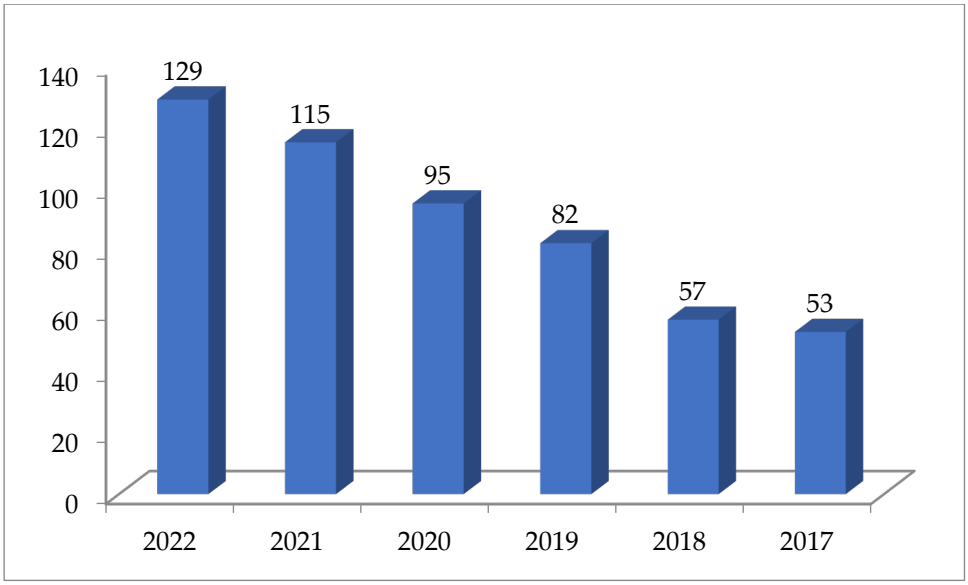

Figure 2. Number of publications in the CSC field between 2017 and 2022.

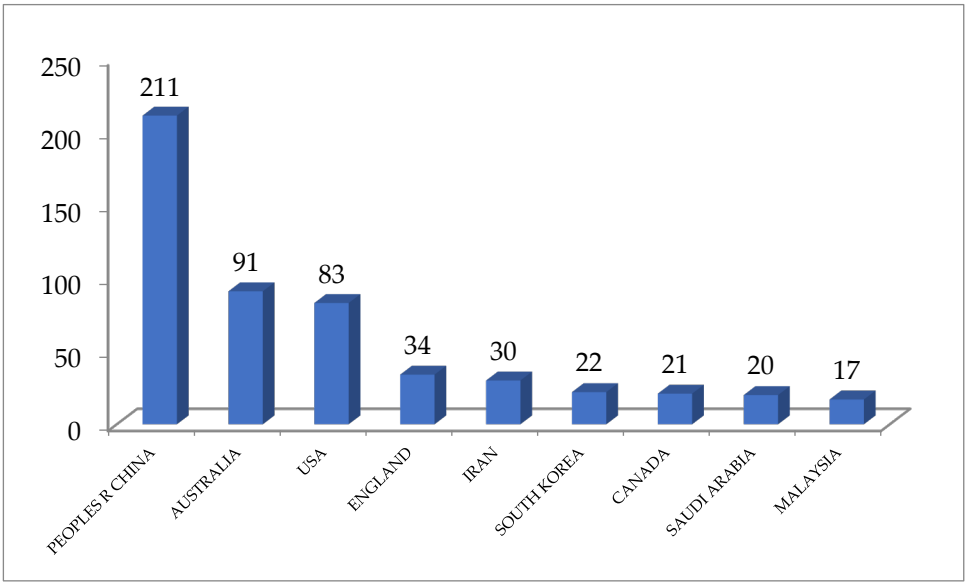

Figure 3. Top productive countries between 2017 and 2022.

3.2. Keyword Analysis

By analyzing keywords of the 531 articles, the core content, research hotspots, and future trends were analyzed. The visualization software VOSviewer is applied to analyze "Keywords" and "Occurrence Frequency", and the results reflected the co-occurrence relationship between keywords intuitively. First, the minimum occurrence frequency of keywords was set to 30, and a certain number of related keywords from 4550 entries was selected. Then, the less closely related keywords were removed, and the final selected keywords were displayed in Figure 4. Furthermore, in order to analyze the co-occurrence relationship between keywords in more detail, the time factor of the first occurrence of keywords was added, as shown in Figure 5. It should be noted that the size of each circle in Figures 4 and 5 represents the weight of this keyword, and the distance between two circles indicates the affinity between the two circles. In general, the stronger the affinity, the

shorter the distance; inversely, the weaker the affinity, the further the distance. The color of the circles represents the respective cluster class.

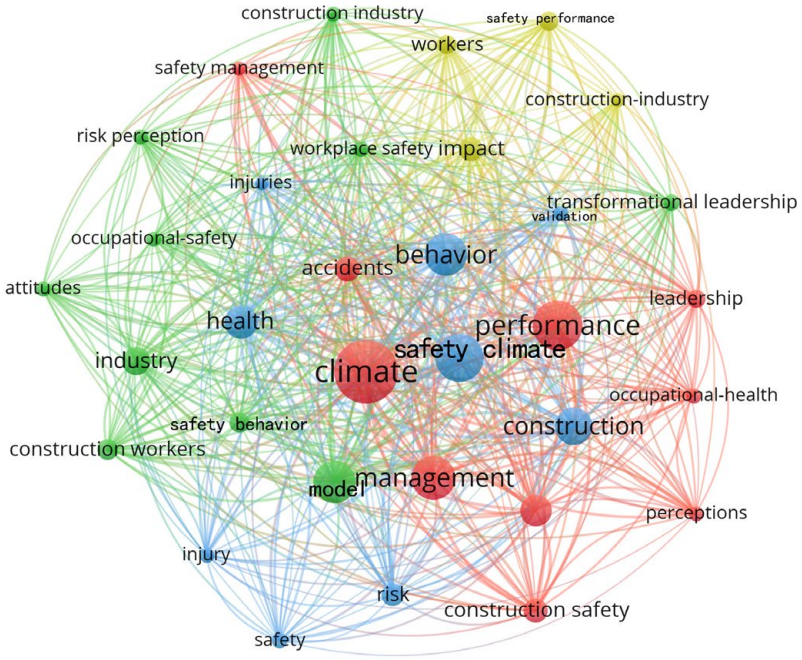

Figure 4. Co-occurrence analysis on the keywords of publications.

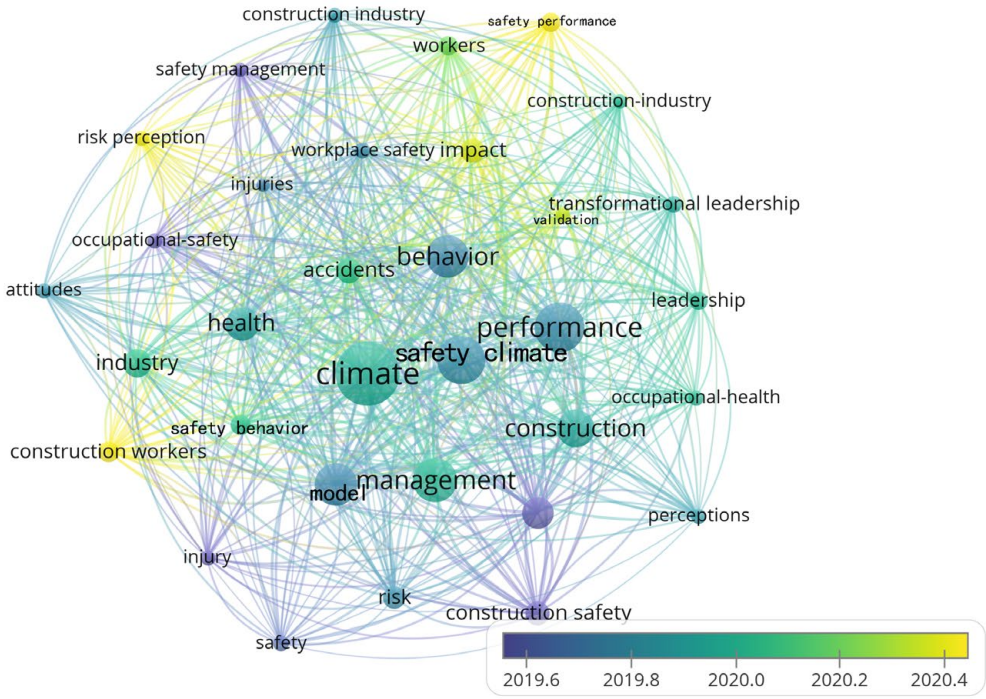

Figure 5. Co-occurrence analysis on the keywords of publications with the addition of time factor.

As shown in Figures 4 and 5, keywords including 'Safety Climate', 'Climate', 'Construction', 'Performance', and 'Management' appear frequently. In conjunction with the time index in the lower right corner of Figure 5, the research trend has moved from 'Safety Climate' to 'Performance' and 'Construction', followed by 'Safety Behavior' and 'Management', and finally to 'Construction Worker'. According to the data of VOSviewer and the

frequency of keywords, 20 keywords with the highest frequency was selected, as shown in Table 1.

Table 1. Appearance frequency of keywords in the field of CSC.

Keyword	Frequency
Climate	246
Performance	177
Safety Climate	168
Management	147
Behavior	140
Model	139
Construction	117
Health	99
Culture	92
Industry	79
Accidents	68
Construction Safety	65
Impact	65
Risk	57
Construction Workers	51
Safety Behavior	48
Workers	47
Safety Performance	45
Leadership	44
Transformational Leadership	39

The lines in Figures 4 and 5 indicate that two keywords are related, similar to the line between 'Safety Climate' and most keywords, indicating that these keywords are more or less related to 'Safety Climate'. Table 1 shows that, despite 'Performance', 'Behavior', and 'Culture' appearing more often, keywords, such as 'SP' and 'Safety Culture', are less frequent.

Taking 'Performance' as an example, it was found that many scholars have conducted performance studies on 'SP' and 'Contextual Performance' [22] or analyzed the performance of certain interventions [23]. In addition, a review had revealed that scholars have been turning their attention in the last two years to the topic of 'Construction Workers' and 'Construction'. For example, Lim, S. studied the impact of the psychological state of construction workers on the CSC and construction safety [24].

3.3. Journal Analysis

Based on the 531 published papers, journals are classified, as shown in Figure 6. It is apparent that 'Safety Science (*Saf. Sci.*)', 'International Journal of Environmental Research and Public Health (*Int. J. Environ. Res. Public Health*)', and 'Journal of Construction Engineering and Management (*J. Constr. Eng. M.*)' have a relatively large number of publications. Among them, '*Saf. Sci.*' is the most widely published, having appeared in 99 journals related to CSC over the past decade, higher than the sum of '*J. Constr. Eng. M.*' and '*Int. J. Environ. Res. Public Health*'.

Then, the influencing factors of journals based on citations were analyzed, as shown in Figure 7. It can be concluded that '*Saf. Sci.*' is the largest in terms of publications, with 1928 citations. '*Int. J. Environ. Res. Public Health*' and '*J. Constr. Eng. M.*' ranked the second and third, respectively. Additionally, 'Journal of Safety Research (*J. Saf. Res.*)' and 'International Journal of Occupational Safety and Ergonomics (*Int. J. Occup. Saf. Ergon.*)' also had a great impact.

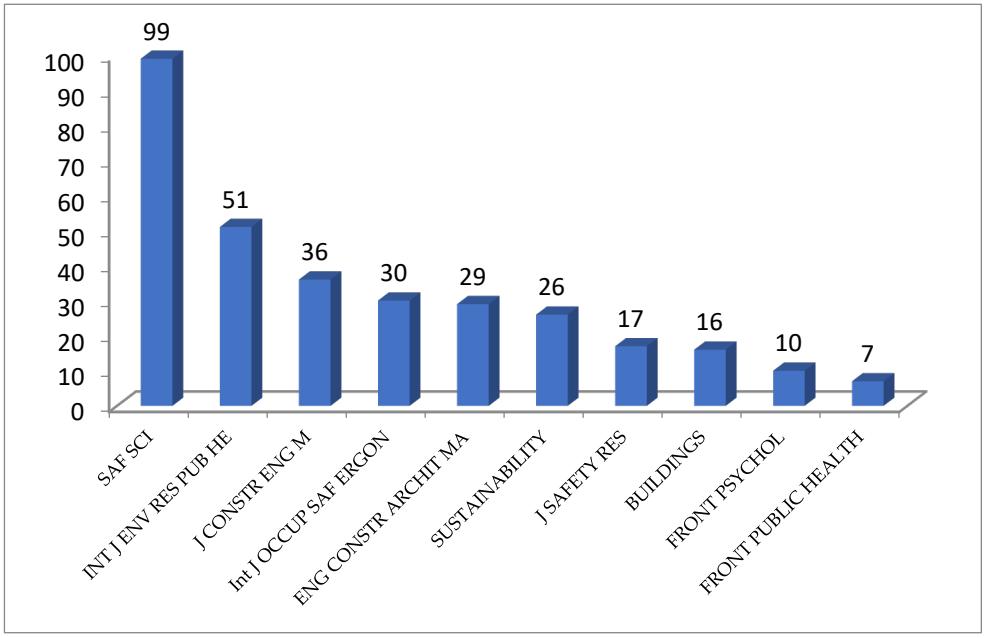

Figure 6. Top 10 journals in terms of publications between 2017 and 2022.

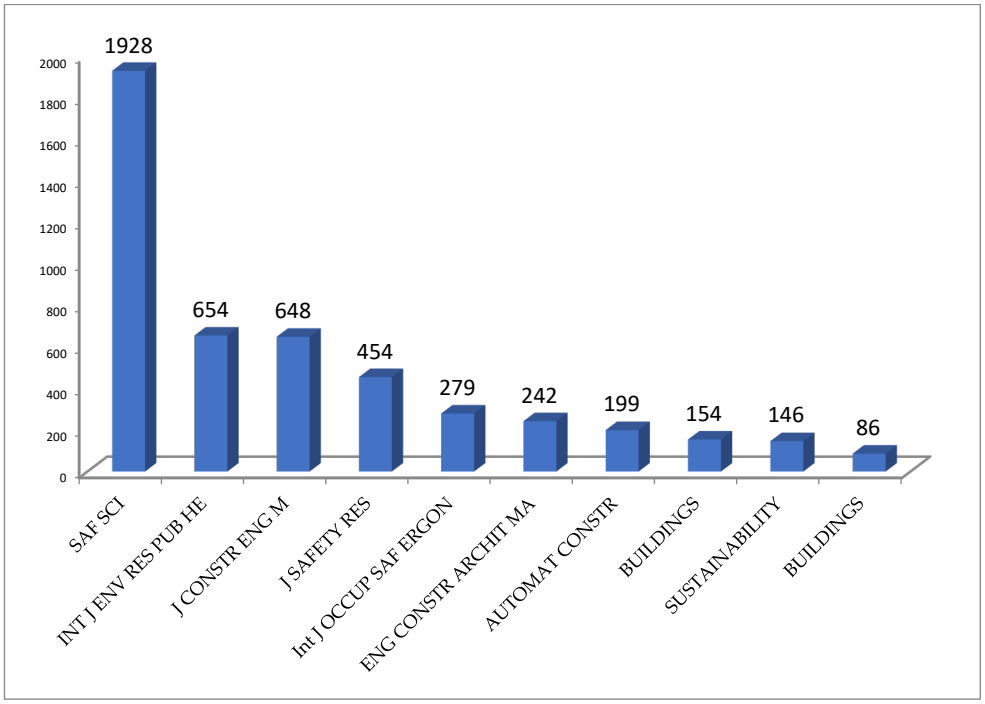

Figure 7. Top 10 journals in terms of literature citations between 2017 and 2022.

3.4. Scholar Analysis

In this section, the number of publications and citations of the authors was shown. The parameters for the minimum number of publications were set to 3, and the minimum number of co-citations was set to 50. As a result, 56 writers were filtered, and the results were shown in Figure 8. The circle in the figure indicates the number of papers published by each scholar, and the thickness of the center line in the figure indicates the strength of the relationship between scholars. Different colors indicate different clusters. Then, the data on the number of citations were added to generate Tables 2 and 3. The next step was to analyze the co-citation relationships between the authors. VOSviewer was configured with the following parameters: the minimum number of documents of an author was set at

4, the minimum number of citations of an author was set at 40, and a total of 51 authors were filtered. Then, the results were visualized to generate Figure 9.

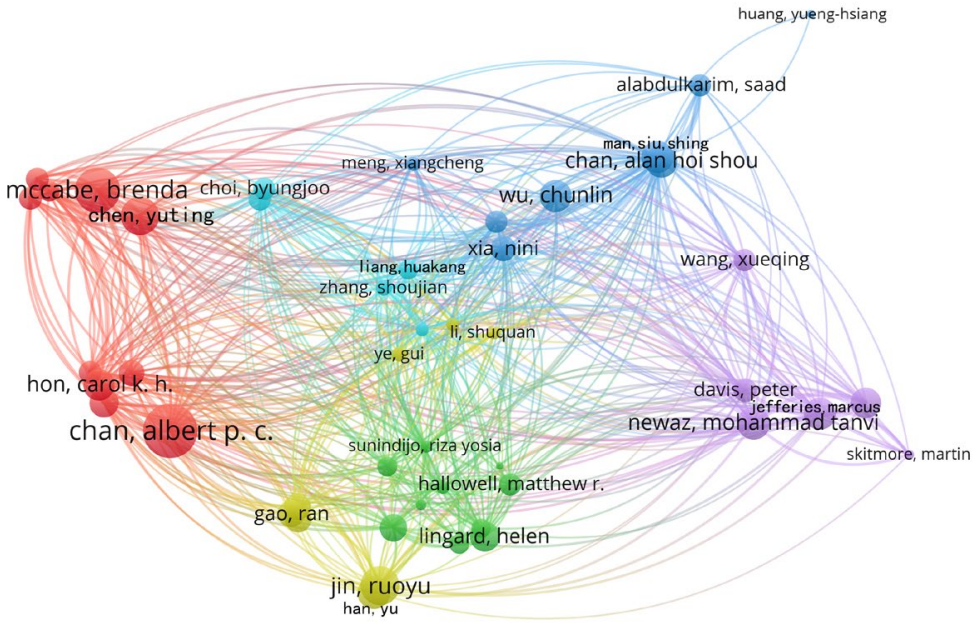

Figure 8. Author co-citation network for CSC research.

Table 2. The top 10 highly cited authors in CSC research.

Author	Citations
Chan, Albert P. C.	333
Mccabe, Brenda	273
Jin, Ruoyu	228
Chen, Yuting	224
Han, Yu	193
Newaz, Mohammad Tanvi	191
Chan, Alan Hoi Shou	188
Man, Siu Shing	188
Jefferies, Marcus	187
Wu, Chunlin	186

Table 3. The top 10 prolific authors for CSC.

Author	Documents
Chan, Albert P. C.	12
Newaz, Mohammad Tanvi	10
Jin, Ruoyu	9
Jefferies, Marcus	8
Lingard, Helen	8
Mccabe, Brenda	7
Han, Yu	7
Wu, Chunlin	7
Hon, Carol K. H.	7
Chan, Alan H. S.	7

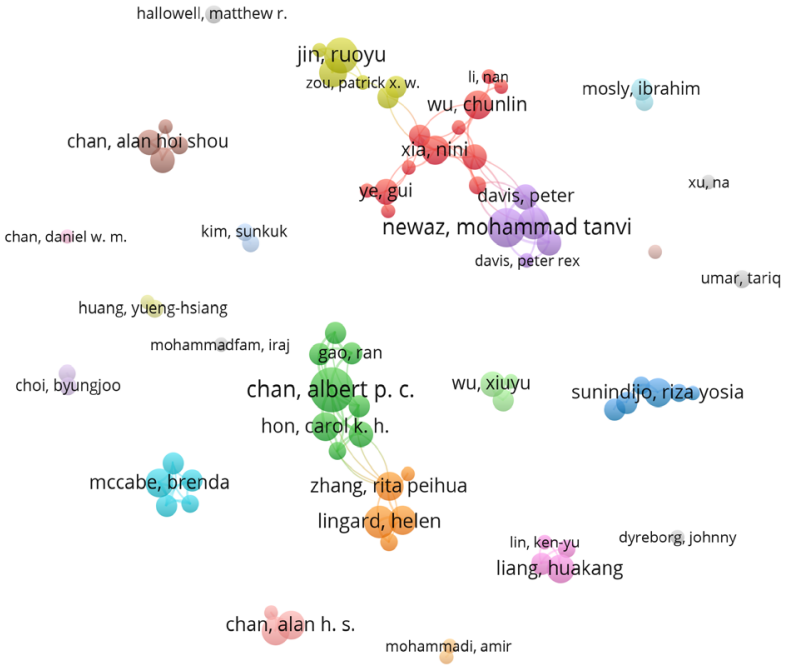

Figure 9. Co-authorship network for CSC research.

From the above information, it can be concluded that Chan, Albert P. C., Newaz, Mohammad Tanvi, and Jin, Ruoyu are the three writers who published the most articles. Chan, Albert P. C., Mccabe, Brenda, and Jin, Ruoyu are the three most-cited authors. It can be concluded that Chan, Albert P. C. has made the highest contribution to the field of CSC in the last 5 years, both in terms of the number of publications and citations. Additionally, by reading the papers of Chan, Albert P. C., it is found that the scholar is more concerned with CSC itself and the relationship between CSC and cross-cutting themes. For example, in 2020, Chan, Albert P. C. proposed a Bayesian network model to encapsulate the interrelationship between safety factors and safety performance. Upon analysis, it was determined that controlling alcohol and smoking habits, safety inspections, and procedural factors in combination was most effective in improving SP [25]. By constructing a structural equation model, Chan found that safety climate and safety behavior are significantly related to one another. Furthermore, CSC is significantly associated with safety behavior and safety outcomes [26]. It is important to note that the number of papers published by Chen Yuting is not among the top, but the number of citations is very high, indicating that Chen Yuting's articles are of very high quality, while the most cited paper "Impact of individual resilience and safety climate on safety performance and psychological stress of construction workers: A case study of the Ontario construction industry" is also published by Chen Yuting. Therefore, when studying the CSC field, apart from focusing on the number of publications and citation rankings, this scholar's research can be referred to.

Figure 9 illustrates the co-citation relationship between different scholars, where authors in the same color cluster are more closely connected and have more interactions with one another.

3.5. Institution Analysis

The volume of articles and co-citation relationship of institutions were visualized by VOSviewer to generate Figure 10. Figure 11 was also generated by organizing and analyzing the number of papers published by institutions using VOSviewer. Table 4 was generated by comparing the top 15 citations of institutions.

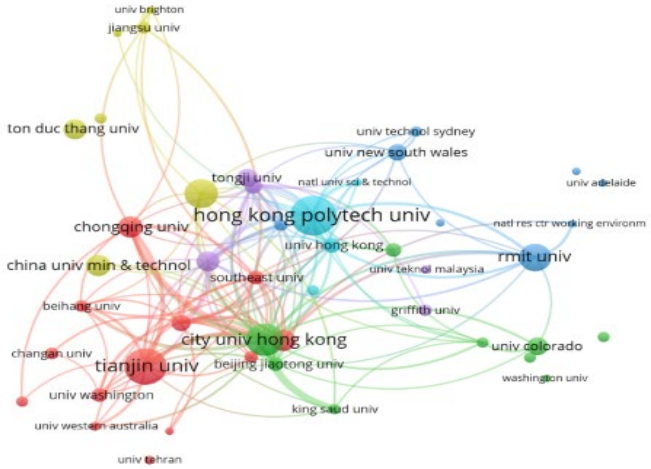

Figure 10. Cooperation network analysis among institutions for CSC.

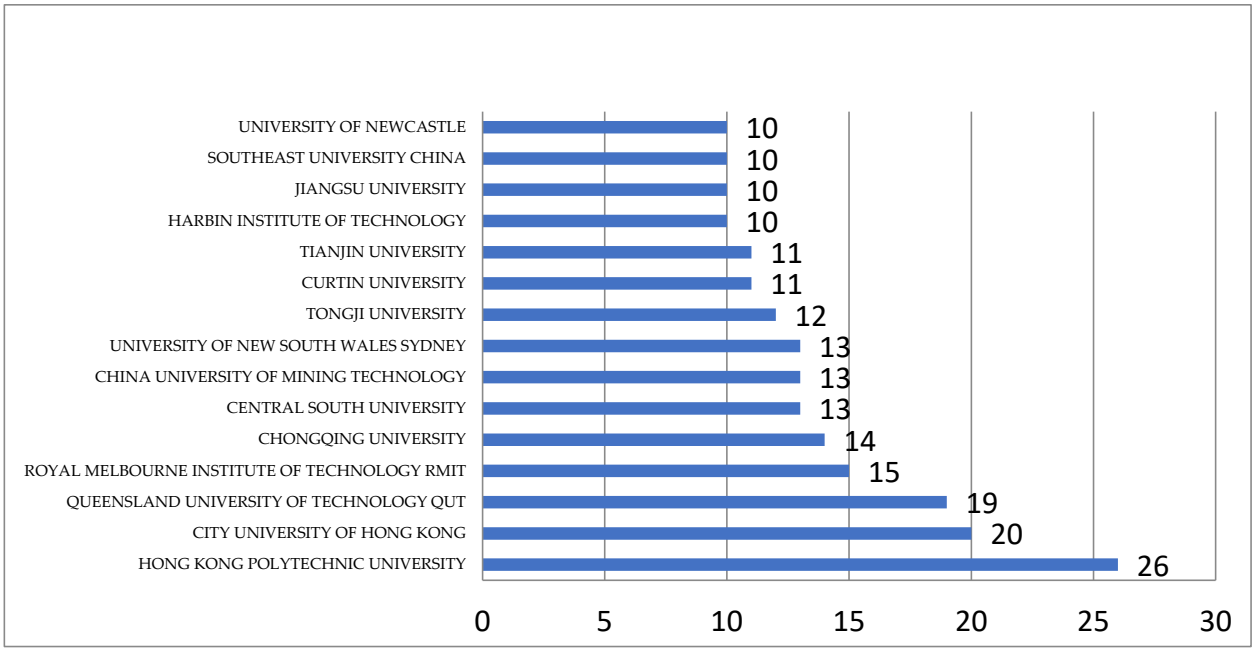

Figure 11. The institutions that produced the top 15 in CSC production volume.

Table 4. The rank of institutions in terms of publications on CSC (Top 15).

Institution	Citations
Tsinghua Univ	401
City Univ Hong Kong	309
Hong Kong Polytech Univ	309
Univ Toronto	246
Tianjin Univ	211
Queensland Univ Technol	210
Rmit Univ	198
Southeast Univ	176
Univ Hong Kong	175
Natl Univ Singapore	170
Ton Duc Thang Univ	158
Beihang Univ	142
Univ Colorado	130
Univ Western Australia	129
China Univ Min & Technol	123

Through the information on the volume of publications and the number of citations, it was found that most of the institutions are universities, and eight of them are from China. Among these eight Chinese institutions, by considering the number of publications and the number of citations, it can be seen that the Hong Kong Polytechnic University has the highest number of publications and the third highest number of citations, with a very high level of influence on research in the CSC field. Tsinghua University has a low number of publications but the highest number of citations, indicating that Tsinghua University is very influential among research institutions in the CSC field. Therefore, when carrying out related research, the research of these two universities should not be ignored. Moreover, we also find that both these institutions come from regions with a high level of economic development, in accordance with our analysis based on the country/region.

4. Result of Qualitative Analysis

Following the scientometric analysis and visualization of CSC-related papers produced over the last several years, this paper will now discuss selected articles in depth. This paper conducts an in-depth qualitative analysis on the hot spot research topics in the CSC field, summarizing the possibilities of future research directions and topics relevant to the field.

Upon visual analysis using VOSviewer, it is evident that there are more research aspects related to CSC, such as 'SP', 'safety culture', 'workers', etc. The following section provides a simple classification of the different studies in the field of CSC, followed by a qualitative analysis.

4.1. Construction Safety Climate

From the above analysis, it can be found that the studies in the field of CSC are conducted in the context of 'Construction'. Therefore, in the first part of the qualitative analysis, this paper explores the CSC and construction-related studies.

According to the research and analysis of related papers, CSC plays an instrumental role in the safety of construction projects. As demonstrated by many studies, CSC will largely affect the safety of the implementation process of construction projects. It is noted that a good CSC can largely prevent accidents, decrease the number of casualties and property losses caused by accidents, and better protect the safety of construction projects [27].

Because of the high incidence of safety accidents in the construction industry, experts have conducted in-depth research on this situation. Many scholars have attempted to measure and deconstruct the CSC by analyzing accidents through various algorithms and models and have found that the higher the level of CSC, the lower the probability of accidents, and that CSC can prevent accidents to a great extent [28]. Other scholars have also taken construction safety accidents as a breakthrough, analyzed the objective precursors of construction deaths caused by construction accidents themselves, and improved the safety climate of the construction industry through building mathematical models to predict the high event rate that may occur in construction operations [29,30]. From the above analysis, it can be seen that experts believe that CSC has a certain preventive effect on the safety of construction projects, but it is also found that the research on how to prevent accidents and the prevention effect of CSC is missing, and the research in this area still needs to be explored by scholars.

Some scholars have also studied the relationship between CSC and construction risk bearing and avoidance and found that there is a significant negative correlation between CSC and construction risk bearing capacity and construction risk bearing capacity. Through CSC, the project can be completed with a lower risk bearing capacity, and more risk avoidance decisions can be made [31]. Several scholars studied the organizational and social factors that led to the increasing pressure in the construction industry [32], analyzed the potential causes, and put forward ideas on how to improve the adverse organizational and social working conditions and pressure in the construction industry [33].

In order to accurately quantify the CSC, scholars have also studied the CSC assessment indexes and divided the CSC assessment into eight factors and six indexes, which allow contractors to self-assess the CSC of the project, help the main contractor to strengthen the safety management system, and improve the maturity of the project's CSC to further ensure the safety of the project [34]. Some scholars are also concerned that workers and managers/supervisors have different views on the CSC, and reconciling these two different views is crucial to mitigate and avoid injuries and fatalities in the construction industry [35].

4.2. Safety Climate and Safety Performance

The relationship between SP and CSC is one of the inseparable topics in the study of CSC-related fields. The SP is defined as the measurable results of the occupational health and safety (OHS) management system based on OHS policies and objectives [36], which is related to the OHS risk control of the organization, and the performance is measurable. The assessment of SP is also an evaluation of the safety capabilities of the construction site [37]. Thus, for this feature of SP, many scholars try to explore the influencing factors of construction SP [11]. For example, the scholar Mosly, I. analyzed the factors affecting SP in the Saudi Arabian construction industry and performed a detailed cluster analysis of 10 major components, such as a healthy working environment, fire prevention, etc., to provide an effective method for different construction industry stakeholders to improve SP and CSC on project sites and to help reduce the occurrence of accidents [38]. Mohammadi, A. also developed a hierarchical framework to show how factors affecting SP affect the safety of construction projects, explored how engineering can optimize SP and CSC, and confirmed that the level of SP and CSC is determined not only by the relevant management activities but also by the interactions between factors at different levels [39]. There is a complementary relationship between CSC and SP [26]; a good CSC is often accompanied by good SP [40], while improving the level of CSC in a project can reduce the occurrence of accidents and further improve SP [41,42]. Some scholars have analyzed the definition and dimensions of CSC and combined the empirical relationship between CSC and SP with statistical meta-analyses to propose the idea that CSC is an important criterion for predicting SP [11,43].

In studying the correlation between CSC and SP, scholars proposed the resilience of CSC, which includes seven aspects, such as safety awareness, sense of safety, and management commitment, and found that the safety awareness of each organizational level of the project largely influences the CSC and SP [44,45], and good safety awareness can drive good safety awareness, leading to an improvement in CSC, which in turn improves SP [46,47]. Agumba, J. N. and Haupt, T. C. found that top management commitment and involvement in health and safety indirectly influenced overall health and SP through mediating variables, such as project oversight, health safety resources, and training [48], these factors also influenced the CSC to some extent [49]. Other scholars analyzed SP from the project level [50], while Guo, B. H. W. et al. assessed the safety level of projects by developing a stress state practice analysis model with indicators and found that the leadership indicator can reflect strengths and weaknesses in the safety status of projects and help to solve safety problems in order to improve SP and CSC [51,52]. In the latest study by Sharifah N.N. Syed-Yahya et al., the positive impact of CSC on SP was highlighted [53].

4.3. Safety Climate and Safety Culture

Safety culture and CSC are also closely connected. It was found that experts have consistently concluded that improving the level of safety culture can effectively improve the level of CSC, while effectively reducing accidents and improving SP indicators [41,54]. Sukamani pointed out that CSC can be positioned as a mediating variable between safety culture and SP, that is, safety culture influences the merit of safety total performance by changing the CSC of the project [10]. Scholars have found in subsequent studies that the maturity of a safety culture is crucial from the perspective of preventing unsafe behavior,

and good safety culture can have a warning and supervisory effect on workers' behavior and contribute to the creation of a safe climate [55,56].

Other scholars have institutionalized the system based on an OHS management system to reduce occupational health and safety risks and have emphasized the importance of fostering an excellent safety culture for construction safety [57].To better understand and develop safety culture and to explore the relationship between safety culture and safety climate, Deepak, M., and Mahesh, G. developed a safety knowledge-based safety culture questionnaire to investigate the impact of safety culture on project safety, i.e., on project CSC and performance [58,59] through questionnaires, factor analysis, and inter-project correlation tests [60]. Other scholars have found a single level in assessing safety culture, and scholars Bhagwat, K. and Delhi, V. S. K. proposed to assess the level of multi-level safety culture in the construction industry more comprehensively by capturing employees' perceptions of safety culture at multiple levels [61]. Through the analysis of the above papers, this study finds that safety culture and safety climate belong to a complementary relationship and that safety culture-related research can largely help other scholars to carry out research on CSC.

4.4. Safety Climate and Worker

From quantitative analysis, it can be found that research related to workers is one of the hot spots in recent years. Through analysis of CSC, safety culture, and SP, it is found that the worker group affect the safety of construction projects most directly [62]. The impact of CSC on workers can be roughly divided into two parts. In the first part, a number of scholars have studied the influence of workers on CSC. For example, some scholars studied the influence of workers' safety behaviors on CSC, which has a positive impact on safety behavior participation and overall safety perceptions [3,63], and through an in-depth study of workers' safety behaviors, the interactions between psychological, physiological, psychophysiological, and individual mechanisms of construction workers' unsafe behaviors (IM-CWUB) were analyzed, and construction safety practitioners were provided with directions on how to reduce unsafe behavior by establishing an integrated framework of IM-CWUB [64]. Similarly, by constructing a theoretical framework for the decision-making process of construction workers' safety behavior, scholars analyzed the factors that affect workers' safety behavior and how they affect safety performance, which has a reference role for the impact of workers' safety behavior on the CSC [65,66]. In addition to the analysis of workers' safety behavior, other scholars have focused on the fact that workers' safety knowledge has an impact on the CSC, and it was found that workers' safety knowledge has positive impact on safety attitudes, which can be used to predict workers' safety behaviors, and further affect CSC [67,68].

Research into the influence of workers' behavioral and psychological causes on safety climate is relatively comprehensive, but research into the influence of workers' personal attributes on safety climate could be expanded, such as workers' education, age, working age, etc. Further in-depth analysis of the causes arising from these reasons still need to be explored [69,70].

Another part is external factors. For example, some scholars have studied family interference with work (FIW) and analyzed the correlation between FIW and worker safety behavior, and it is found that FIW can predict the safety behavior of workers, and that effective intervention design can protect the health of workers, and affect the construction SP and CSC to a certain extent [71]; in addition to the family aspect, scholars found that supervisors' violations have an indirect effect on workers' behavior; supervisors' violations lead to a greater likelihood that workers will violate safety rules, which in turn leads to unsafe behavior and affects the SP and SC of the project [72]. It has also been noted that safety training has an impact on workers' behavior [73,74], which in turn affects CSC and SP. Some scholars have even been creative in finding that different nationalities of construction workers, different religious beliefs, and whether they are employed by a subcontractor or a prime contractor have a degree of influence on worker behavior and how workers

perceive the SC [14]. However, many external factors remain to be discovered and explored by scholars.

5. Conclusions and Future Directions

5.1. New Challenges for the Safety Climate

Through scientometric and qualitative analyses of CSC-related research in recent years, the research history and hot trends were sorted and analyzed. In addition, the four areas of 'Construction', 'SP', 'Safety Culture', and 'Worker' in the field of CSC were analyzed separately in terms of research directions. It is found that research on the influence of workers on CSC has been most readily discussed by scholars in recent years. However, the number of studies on in-depth understanding of the CSC concept and updating the CSC measurement model has significantly decreased [75], with only five in 2022. Alamoudi, M. [76] proposed the latest research on the CSC dimension. He combined NOSACQ-50 with the importance–performance analysis (IPA) technology to measure and use IPA to determine the strengths and weaknesses of each dimension [76]. As with most studies in recent years, the focus is more on the importance and priority of dimensions but did not further expand the dimension of CSC measurement. Meanwhile, scholars' research on cross-sectional themes, such as the relationship between CSC and SP or CSC and safety culture, has also decreased significantly compared to the previous studies [77], and there are only eight papers in 2022. Therefore, this paper believes that there are still many research fields worth exploring in CSC-related fields. It is clear that in terms of the total number of annual publications in the safety climate, the volume of publications is under-represented. The latest research of Sharifah N.N.Syed Yahya reviewed the relationship between CSC and SP, revealing a common problem that most scholars lack strong evidence on how to improve the causal relationship of CSC when conducting relationship research [53]. Scholars need to pay more attention to causal relationships in future studies.

According to the analysis, scholars have made new advances in their research themes over the past few years. A growing number of scholars have begun to investigate the impact of safety climate on construction safety from the perspective of workers [78]. There are scholars who analyzed the attitudes of different participants in construction projects toward safety and discussed the extent to which their actions influence safety [79,80]. However, the analysis revealed that scholars have focused on groups of workers and project managers, but project participants are not limited to these two groups, and more attention should be paid to other project participants as well. On the other hand, scholars' analysis of the impact of workers on CSC is mostly limited to the dimension of workers' behavior [81], and the analysis of workers' behavior is also limited to the study of the motivation and psychology of workers' behavior, which is not enough to comprehensively analyze how workers' behavior is affected by other factors, and there is still much room to explore the root cause of workers' behavior. Therefore, this paper argues that research in CSC-related areas still worth exploring. In addition, there is less research and exploration in the area of combining CSC with on-site construction processes, which could be a future research direction for scholars.

5.2. Future Directions for the Safety Climate

The literature cited in this study is collected based on data from the WOS database for the past 5 years and only covers mainstream journals searched by SCI and SSCI, without combing any conference papers and research results, resulting in a small sample size of literature that meets our research objectives, leading to the limitations of this study. Then, the qualitative analysis of this paper is based on the analysis of keywords, published journals, and research topics in the field of CSC, and the qualitative analysis of mainstream research topics, and this paper identifies several predictable future research directions in the field of CSC:

(1) Update existing safety climate research models based on findings from cross-cutting themes, such as safety management, e.g., update the measurement model for CSC

assessment to make the model indicators applicable to CSC assessment in most situations and requirements (including project complexity, cross-cultural or not, different levels of site conditions, etc.) according to the different requirements for CSC in different countries and regions.

(2) Analyze the role of different parties involved in a construction project in the process of CSC construction, and how each of them can affect the CSC.

(3) Combine the creation of CSC with BIM and other software to measure the CSC from the design stage and analyze predictable problems in the creation of CSC in project construction [82].

(4) Analyze the influence of different groups of workers and organizations on CSC; for example, what differences are associated with steelworkers, carpenters, and installers.

(5) Combine the need for prevention and control in the post-epidemic era with the study of CSC and discuss the impact of CSC in this situation and the corresponding adjustments needed to build and improve the CSC in this situation.

(6) Systematic research on how the safety climate predicts unsafe behaviors of workers and unsafe accidents that occur in the project, and systematic analysis of the design of prediction mechanisms, risk warnings, and other links.

5.3. Conclusions

In this study, 531 journal articles in the field of CSC were used as a sample of the literature which were analyzed quantitatively and qualitatively by using the scientometric method and VOSviewer visualization software. It was found that the number of articles issued in recent years has been increasing annually, and the number of articles issued in 2022 ranked the highest; in terms of the regions where the articles were issued, it was indicated that a higher number of articles were issued in regions with better economic development, such as China, the United States, and Australia. The analysis of the journals showed that 'Safety Science', 'International Journal of Environmental Research and Public Health', and 'Journal of Construction Engineering and Management' are the most published and high-quality journals in the field of CSC. From the perspective of scholars, based on the quantity and quality of publications in the past five years, Chen, A.P.C. and Chen Yuting are the most outstanding scholars in the field of safe climate, while, from the perspective of publishing institutions, Tsinghua University and Hong Kong Polytechnic University have a very important position in the field of safety climate research. Furthermore, the qualitative analysis of keywords and themes revealed that the research on the relationship between SC and SP and safety culture is more than adequate, except that in recent years there has been little update on related areas and no update on the existing research with the development of time and the current situation of society. Many scholars also explain how SC affects SP and safety culture indicators from the perspective of CSC influencing factors, and describe the impact process between them by establishing a more comprehensive model. Different scholars also have different focuses on the impact of workers on CSC. Some scholars focus on the unsafe behaviors of workers, while others focus on internal and external reasons of workers. Everyone has their own innovation.

This paper finds that CSC not only has a very important role in building construction and ensuring construction safety, but also has a positive role in ensuring the health and safety of construction workers. As such, CSC and SP safety culture have an inseparable relationship, which also have an impact on construction safety.

In summary, this study provides an overview of the hot research topics in the CSC field in the past few years and puts forward suggestions for future research development in the field of safety climate in response to the problems identified in the study.

Author Contributions: Conceptualization, X.L. and Z.X.; methodology, X.L. and Z.X.; formal analysis, S.C. and Z.D.; investigation, Z.D. and S.C.; data curation, X.L.; writing—original draft preparation, Z.X.; writing—review and editing, X.L.; supervision, X.L. All authors have read and agreed to the published version of the manuscript.

Funding: Philosophy and Social Science Research in Colleges and Universities in Jiangsu Province (No. 2020SJA1394), Fundamental Research Funds for the Central Universities (No. 331711105), Jiangsu Provincial Construction System Science and Technology Project of Housing and Urban and Rural Development Department (No. 2017ZD074), Postgraduate Research & Practice Innovation Program of Jiangsu Province (SJCX22_1568).

Institutional Review Board Statement: Ethical review and approval were waived for this study, due to the fact that this study did not involve biological human experiment and patient data, which was not within the scope of review by the Institutional Review Board of Suzhou University of Science and Technology.

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: The data presented in this study are available on request from the corresponding author.

Acknowledgments: The authors would like to appreciate the reviewers for all helpful comments.

Conflicts of Interest: The authors declare no conflict of interest.

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