ASPS Conference Proceedings 1: 1175-1183 (2022)

Proceedings of

12th Structural Engineering Convention-An International Event (SEC 2022)

Available at https://asps-journals.com/index.php/acp

Mapping of Global Construction Safety Research using Scientometric Approach

D.A. Patel [1; *], S.B. Amlani [2]

[1] Department of Civil Engineering, Associate Professor, Sardar Vallabhbhai National Institute of Technology, Surat 395 007, India
[2] Department of Civil Engineering, Ph.D. Research Scholar, Sardar Vallabhbhai National Institute of Technology, Surat 395 007, India

Paper ID - 080400

Abstract

The construction sector is one of the hazardous sectors across the world. In the Indian construction sector, on an average 38 fatal accidents happen every day. Research on construction safety and improvement of safety performance has been continuing for a few years. It explores multiple areas such as safety performance measurement, safety program, human factors, safety planning, site monitoring, etc. This study followed a three-stage literature review approach summarizing the research domain of construction safety. The science mapping approach consists of both bibliometric analysis and scientometric analysis which are carried out in this study. For the bibliometric analysis, Web of Science (WoS) database has been used while for the scientometric analysis, the Cite-Space software has been used in this study. This study identifies key areas of construction safety management by following by a qualitative discussion on research publications across the globe. It includes information and communication technology in safety management, workers' safety perception and behaviour, safety management system, hazard identification, accident causation, and risk management in safety, safety climate and safety culture. This study helped the authors to prepare the outline of construction safety manual. This paper is useful to academic community and industry practitioners to understand the trend of research in the field of construction safety. Also, the proposed directions for future work could benefit to the new researchers and industry practitioners in enhancing safety performance and improving site 'employees' health and wellbeing.

Keywords: Scientometric Analysis, Construction Safety, Work Zone Safety.

1. Introduction

Constructions sector is one of the hazardous sectors across the world. In the Indian construction sector, on an average 38 fatal accidents happen every day [1]. Similar challenges exist in other countries [2]. Research on construction safety and improvement of safety performance has been continuing for a few years. It explores multiple areas such as safety performance measurement [3], safety program [4], and human factors [5]. Recently the application of digital technology such as BIM (i.e., Building Information Modeling) has been growing in the construction sector. Researchers have commenced the use of BIM in enhancing safety planning and site monitoring [6]. The literature review encompasses all existing literature on a given subject, in the sense of what is newest on this subject. Conducting the literature review is an expedient method to gain an in-depth understanding of a research domain. However, limited studies exist which review covers these issues as mentioned above (e.g., safety program, BIM, and human factors, etc.).

One of authors of this study needs to identify the key areas of construction safety management to determine the outline of a construction safety manual which is a part of project sponsored by National Highway Authority of India (NHAI) New Delhi. Moreover, there is a boundary between the study of construction safety and road safety. Many accidents are reported in work zones while road and bridge construction or maintenance work is in progress. This study includes construction safety with work zone safety management too.

A scientometric analysis approach has been adopted in the field of construction engineering and management [7]. It aims to address the subjectivity issue. However, these existing scientometric review-based studies were bounded to self-exploratory topics such as the most productive scholar, the most influential journal, and the most frequently searched keywords [8]. The level of details presented in these previous reviews could be enhanced [8]. This review-based study applied the science mapping approach by reviewing journal articles published in the domain of construction safety. The objectives of this report consist of (1) applying a science mapping approach to analyze the influential journals, keywords, scholars, and articles in the domain of construction and work zone safety; (2) analyzing the existing mainstream research topics in construction and work zone safety; (3) determination of key areas of construction safety management for the preparation of construction safety manual, (4) discussing the limitations or gaps of existing research in the construction safety domain; and (5) proposing the research framework guiding future

*Corresponding author. Tel: +91 99982 77731; E-mail address: dapscholar@gmail.com

Published online: December 19, 2022
doi:10.38208/acp.v1.637

scholarly and research work. This review-based study introduces the science mapping approach and exposes state of the art into the domain of construction and work zone safety.

2. Methodology

This study followed a three-stage literature review approach summarizing the research domain of construction safety. The science mapping approach consists of bibliometric analysis and scientometric analysis. Both analysis' are carried out in this study. The bibliometric analysis is carried out using Web of Science (WoS). And, scientometric analysis is carried out using Cite-Space software for this study. The detailed workflow of the review is presented in Fig. 1.

2.1 Bibliometric search

The first step of the review was the bibliometric search in 'Web of Science (WoS)'. The keywords "construction safety", "work zone safety", "bridge", "road", and "highway" were inputs to search literature published in WoS. WoS covers many reputed and qualitative journals and more recent publications. Initially, 1,431 documents were found. These documents were further screened by. including only journal articles published in English. Conference and proceeding papers were excluded from the sample because they have been released in a large quantity but with less valuable or useful information compared to journal articles. After this initial screening, a total 851 articles remained in the literature sample. As shown in Fig. 1, further refinements of the remaining 851 articles were studied of their titles, abstracts, and keywords in detail. Out of these, similar articles that did not focus on safety issues in the construction industry were removed. More, it should be noticed that the scope of this review-based study is covered human-centered safety management, which covered safety planning and site management. However, it excluded other safety issues that do not directly focus on construction employees' safety, such as structural or material safety for buildings. After the final round of screening, ultimately, a total of 382 journal articles published from 2010 to 2019 were selected as the literature sample for the follow-up scientometric analysis.

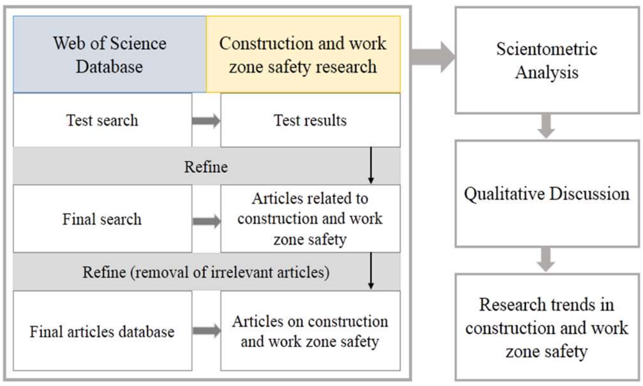

Fig. 1. Illustration of the three-step literature review process

2.2 Scientometric analysis

The second step of the review involved a scientometric analysis method by utilizing the text-mining tool Cite-Space [9]. More background information on scientometric analysis can be found in Hossein et al. [10]. Cite Space creates distance-based visualizations of networks where the distances among nodes show the level of closeness among them. The Cite Space is suitable for visualizing more extensive networks with special text mining features. The scientometric analysis is carried out using Cite-Space software. The obtained literature sample from the bibliometric search is transported into Cite-Space to carry out the scientometric analysis. Further, generated results related to the influences of journals, keywords, scholars, and articles in the domain of construction and work zone safety are discussed in this study.

2.3 Scientometric analysis

The keyword analysis and articles analysis are carried out as part of preliminary study for scientometric analysis by following citation and document analysis. It shows research trend in construction and work zone safety. Further, qualitative discussion and scientific mapping are done in-depth for key research domains. The research domains are (1) Information and communication technology in safety management, (2) Workers' safety perception and behavior, (3) Safety management system, (4) Hazard identification, accident causation, and risk management in safety, and (5) Safety climate and safety culture. The qualitative discussion of the key research domain aims to provide an in-depth evaluation of the research objectives the domain of construction and work zone safety, the current research gaps or limitations and future recommended research work.

3. Findings and Discussion

The 328 journal articles were firstly summarized according to their publication year. Fig. 2 displays the articles' distribution of publication years.

Fig. 2 shows that more articles have been published since 2010. Afterwards, 2010, the number of articles has been undergoing an increase every year except in 2014, 2016 and 2017. It reveals that more research work would be published in construction safety, which is an everlasting research domain in the field of construction engineering and management.

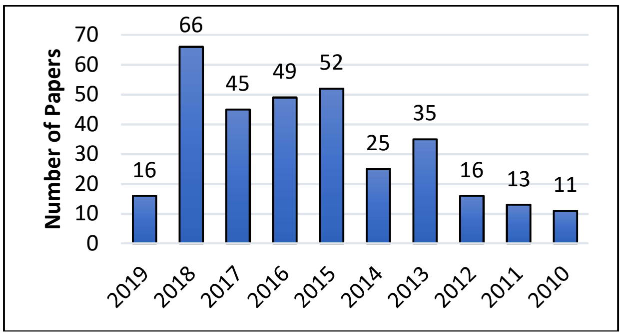

Fig. 2. Distribution of journal articles by Publication years (articles published in 2019 are up to the end of February)

3.1 Journal sources

Besides the annual number of articles published, the journal sources of them were also summarized. According to the node and font sizes, Fig. 3 shows that Journal of Construction Engineering and Management (JCEM) has been the most productive journal in terms of the total number of publications, followed by Safety Science, Accident Analysis and Prevention, and Automation in Construction. The colours and connections lines indicate the interrelatedness among journals, showing journals that have cited each other's articles. For example, these journals have been actively citing each other: JCEM, Safety Science, Accident Analysis and Prevention, and International Journal of Project Management.

More quantitative measurement of the influence of journals is provided in Table 1. Journals in Table 1 are listed according to their Citation. Two journals (i.e., Journal of Construction Engineering and Management, and Safety Science) are the most influential in construction safety research in terms of total Citation. Journals including Automation in Construction, Accident Analysis and Prevention, Journal of International Project Management, Journal of Safety Research, Applied Ergonomics, Safety Science, and Journal of Civil Engineering and Management published articles in the construction safety domain actively. In contrast, other journals seem not to continue active in published articles in construction and work zone safety, such as Building and Environment, Construction Management and Economics, and Journal of Performance of Constructed Facilities.

3.2 Keywords analysis

Keywords show core contents of existing studies and describe research topics within a given domain [11]. Co-occurrence of keywords demonstrates the inter-closeness among them. By using "Keywords" and "Keyword plus" in Cite Space and text mining of research keywords was performed to eliminate general keywords and to combine semantically consistent keywords such as "BIM" and "Building Information Modeling," was combined. Finally, most frequent and trending keywords were generated from the science mapping shown in Fig. 4. These keywords have been more frequently used in previous research of construction safety, including "accident", "model", "construction safety", and "safety management".

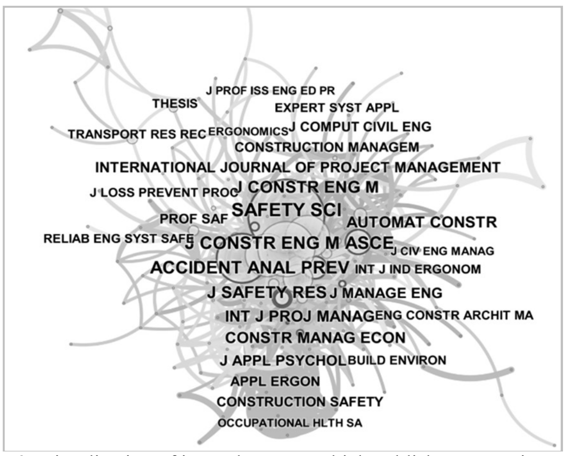

Fig. 3. Visualization of journal sources which publish construction and work zone safety

Table-1. Top 13 Journal based on their citations

Sr. No.	Journal	Times Cited
1.	Journal of construction engineering and management	344
2.	Safety science	249
3.	Accident analysis and prevention	180
4.	International journal of project management	179
5.	Journal of safety research	162
6.	Automation in construction	110
7.	Construction management and economics	102
8.	Journal of applied psychology	71
9.	Journal of management in engineering	68
10.	Construction management	55
11.	Applied ergonomics	53
12.	Journal of computation in civil engineering	52
13.	Professional safety	49

The connection lines in Fig. 4 show the interrelatedness between a pair of keywords. The keyword "accident" highlights accidents occur in the construction sector, and it is found with close links to model and climate and safety performance. Figure 4 seems very complicated, and interrelatedness among all keywords is not visible. It shows the complexity of the subject. To get a better understanding, it can be referred on the model in place of referring the above figure 4. Keywords in Fig. 4 can be divided into several clusters. Keywords within the same cluster generally have closer internal relationships. The font size indicates the frequency of the keyword that has been studied in the selected literature sample. These most frequently studied keywords include safety management, accident, behaviour, risk, model, and design. It is noticed that keywords listed in Table 2 follow the ranking of the occurrence of keywords in a given year. Cite-Space does not provide details of the Average Normalized Citation and Average Citation number. By ranking of keywords using Average Normalized Citation, they are likely to provide details of higher impact areas in the research community of construction safety. The Average Citation number shows the recentness of keywords being studied and published.

Fig. 4. Visualization of authors' keywords in literature

3.3 Citation and Documentation Analysis

Citation analysis was conducted using Cite-Space. In this study, a minimum number of documents and minimum citation number of a scholar were set at 5 and 30 respectively. Top ten authors, according to the number of publications are provided in Table 3. As in Table 3, Fang, D P, although with only 12 articles in total from the literature sample, has the highest influence measured by the number of records available. In terms of Citation shown in Table 4, Hinze, J., and Choudhry, R.M., can be considered scholars with the highest contribution to the academic community of construction safety.

Table-2. Top 25 keywords

Sr. No	Keyword(s)	Occurrence	Avg. Publication Year
1.	management	70	2012
2.	model	69	2011
3.	accident	64	2010
4.	performance	64	2010
5.	industry	57	2010
6.	construction safety	49	2011
7.	system	48	2010
8.	behavior	46	2011
9.	climate	44	2011
10.	safety	41	2010
11.	culture	33	2011
12.	project	33	2010
13.	risk	32	2011
14.	construction	32	2012
15.	design	28	2010
16.	health	27	2011
17.	safety management	22	2012
18.	injury	21	2011
19.	site	19	2012
20.	worker	18	2013
21.	occupational safety	17	2013
22.	environment	17	2012
23.	construction industry	17	2015
24.	road safety	16	2015
25.	Hong Kong	16	2011

Table-3. Top10 authors according to number of publication

Sr No	Author name	Affiliation	Email	Records
1.	D. P. Fang	Tsinghua University, Beijing, China	fangdp@tsinghua.edu.cn	12
2.	Helen Lingard	RMIT University, Australia	helen.lingard@rmit.edu.au	10
3.	H. Li	The Hong Kong Polytechnic University, Hong Kong	bshengli@polyu.edu.hk	9
4.	Matthew Hallowell	University of Colorado at Boulder	matthew.hallowell@colorado.edu	8
5.	Jochen Teizer	Georgia Institute of Technology, USA	teizer@gatech.edu	8
6.	Patrick X.W. Zou	University of New South Wales, Australia	p.zou@unsw.edu.au	7
7.	Albert Chan	The Hong Kong Polytechnic University, Hong Kong	albert.chan@polyu.edu.hk	6
8.	L.Y. Ding	Huazhong University of Science & Technology, China	dingly_wuhan@yahoo.com.cn	6
9.	Murat Gunduz	Qatar University, Qatar	gunduzm@metu.edu.tr	6
10.	X. G. Wu	Huazhong University of Science and Technology, China	-	6

Table-4. Top10 authors according to number of Citations

Sr No	Author name	Affiliation	Email	Citation
1.	Jimmie Hinze	University of Florida, USA	-	83
2.	Rafiq M. Choudhry	Al Imam Mohammad Ibn Saud Islamic University, Saudi Arab	choudhry03@gmail.com	56
3.	Dov Zohar	Israel Institute of Technology, Israel	dzohar@tx.technion.ac.il	56
4.	Sherif Mohamed	Griffith University, Australia	s.mohamed@mailbox.gu.edu.au	52
5.	D. P. Fang	Tsinghua University, Beijing, China	fangdp@tsinghua.edu.cn	48
6.	C.M. Tam	City University of Hong Kong, Hong Kong	bctam@cityu.edu.hk	45
7.	Matthew Hallowell	University of Colorado, USA	matthew.hallowell@colorado.edu	44
8.	Helen Lingard	RMIT University, Australia	helen.lingard@rmit.edu.au	44
9.	John A. Gambatese	Oregon State University, USA	john.gambatese@oregonstate.edu	39
10.	Dom Cooper	Independent Researcher	-	38

3.4 Research Trends in Construction and Work Zone Safety

Following the bibliometric analysis and science mapping of the selected literature sample, the in-depth qualitative discussion now focuses on summarizing the main research topics within the theme of construction and work zone safety, identifying the existing research gaps as well as determining contents for construction safety manuals for construction safety.

3.5 Information and Communication Technology (ITC) in safety management

Information and communication technologies (ICT) have been emerging in the global construction industry. For example, keywords BIM and VR are both digital technology and are linked to each other to be applied in safety management. However, VR is more commonly applied in safety education and training, while BIM can be more widely applied in various safety management activities such as design for safety and site planning [12] [13].

BIM has displayed its role in safety management in existing studies [14] [15] such as training for workers in off-site construction by increasing workers' hazard awareness [16], visualization of scaffolding and safety facilities for accident prevention [17], and developing databases of near-miss events on-site [18]. Besides BIM, VR has shown its influence in safety training and education [19], specifically in hazard recognition and risk identification in the virtual environment [20] and improving the communication between designer and builder [21]. Multiple other digital tools or media such as sensor-based technology, 3S (GIS/GPS/RS) technology, radio frequency identification (RFID), as mentioned by Zhou et al. [22] could be integrated to assist construction safety management. For example, Cheng and Teizer [23] used real-time data collection, processing, and visualization through remote sensing and VR to monitor site safety condition. Aguilar and Hewage [24] developed a real-time safety indicator from a centralized safety database with ICT to assist site managers' site decision making; Zou et al. [25] applied a cloud-based safety information and communication system to improve road construction safety.

There are multiple common hazards on construction sites, such as fall, struck by, and caught-in-between. More ICT-based platforms, prototypes, or user interfaces could be extended to incorporate these main hazards on-site. A step forward of the existing research in applying BIM for safety hazard identification could be to create a prototype that automatically updates hazard assessment the as-planned BIM as the project progresses. Hazard assessment is the occurrence, severity, and risk level according to the existing safety database. More importantly, the established ICT-based prototype or frameworks [26] could be further tested with more real-world cases, including its user-friendliness, users' readiness, acceptance, and easiness for safety communication. From the technical perspective, the interoperability among multiple ICT tools (e.g., BIM and wireless sensing) are to be allowed for information exchange during real-time data collection, and processing needs to be further studied.

ICT could assist design for safety in pre-construction stages. As the construction project progresses, there could be updated in BIM model by incorporating workers' latest activities through site data collected by wireless sensing technologies. Therefore, safety managers are kept updated with workers' physical status and work progress. Safety managers can also be informed of potential hazards that might hold workers at risk as workers' tasks change or the project progresses. More future work can be performed in bridging the manager's monitoring of workers' safety and workers' self-awareness of safety hazards through ICT tools. Besides the technological innovation, the readiness of workers and management personnel to adopt newly developed ICT platforms should also be considered.

3.6 Workers' Safety Perception and Behavior

Workers health and safety on construction sites have been largely focused when applying ICTs. For example, Yi and Wang [27] used a mixed-integer linear programming approach to optimize workers' site work schedule under hot outdoor weather condition. Workers' are exposed to unpleasant weather (e.g., hot temperature), which has caught the attention of multiple researchers [28] [29]. Park et al. [30] developed and evaluated a proximity detection and alert system using Bluetooth sensing technology. It aims to protect the health and safety of pavement workers. Many studies have explored workers' demographic or subgroup features, such as minority or immigration workers [31], workers from different experience levels [28], and workers from different building trades [32]. The causes of workers' variation in their safety perception, attitudes, behavior, and performance have been linked to dimensions within safety climate such as safety awareness and co-workers attitudes [33], safety program, company size [34], and management methods [35]. The causal connection analysis conducted by Winge et al. [36] showed that supervision strongly affected workers' safety actions.

Various groups and subgroups of labour are working simultaneously in a construction project. Subgroup factors of workers (e.g., age and site experience level) could cause different safety perceptions [28], further leading to varied safety behavior [37], and ultimately safety performance [38]. Besides these internal influence factors, there have been limited studies of how the external conditions of job sites (e.g., lighting, temperature, spatial crowdedness) affect workers' safety perception, behavior, and performance. Workers' safety perceptions towards site hazards and risks could be further linked to their safety cognition pattern. There have been limited studies linking their cognition patterns (e.g., safety knowledge-based, prior scenario-based, and basic assumption-based) into safety perceptions. Furthermore, the cognition psychology or cognitive model, although having been studied in other industries or fields such as traffic [39] [40] have not been sufficiently applied in construction safety, especially in workers' safety perception or behavior [41].

3.7 Safety management system

A significant correlation exists between management commitment and safety performance [42]. An effective safety program incorporating the management commitment as well as training and education could ultimately lead to improved safety performance [43]. Participation in safety management should not be limited to contractors, but other stakeholders such as the owner, consultants, vendors, and subcontractors [44]. Researchers have been working on developing a safety management plan that a typical contractor can adopt [45]. Key factors within the safety management programs have been studied to explore their inter-relationships. For instance, Bavafa et al. [46] found that safety commitment and responsibilities, subcontractors and personnel's selection, safety supervisor and professionals, plan for safety, and employee involvement were key critical factors to have an improved safety program.

Similarly, a total of 16 critical factors influencing the success of a construction safety program was identified and tested by Aksorn and Hadikusumo [47]. Similar studies investigating critical factors for effective implementation of a safety management system can be found in Pereira et al. [48] and Yiu et al. [49]. The subcontracting nature of the construction industry indicates that an effective safety program should gain the joint-effort among multiple organizations to maintain consistent safety compliance, which could be evaluated based on behavior-based safety rules [35]. The conflicting objective between site productivity and safety, as indicated by Sandberg and Albrechtsen [50] needs to be handled correctly in the safety reporting process, which should be part of an effective management program.

3.8 Hazard Identification, Accident causation, and Risk Management in Safety

Hazard identification, accident investigation, and risk assessment have been long-standing research topics within construction safety management. Pereira et al. [48] found that the highest-priority accident precursors are workers' failure to identify hazards and negligence of hazards. Earlier studies have been focusing on proper protective equipment

[51], accident types, and physical barrier elements [52], causes of accidents or incidents [53], safety training [54], and effective management program [55]. More recent studies have been emphasizing on ICT (e.g., BIM) as the digital approach in mitigating safety risks. Safety should be considered in the design stage when hazards can be identified in the ontology-based semantic modeling [56].

3.9 Safety Climate and Safety Culture

Multiple studies have been focusing on developing, testing, and evaluating the framework of safety climate or safety culture [57] [58], as well as linking them to safety performance measurement [59]. Key indicators within the safety climate [59] [60] is being kept updated and validated using statistical methods such as SEM [61]. Commonly defined elements within safety climate include but are not limited to management commitment [62], co-workers caring and communication [63], and safety behavior [64]. High attention within safety climate has been paid on workers, such as worker behavior [65], safety compliance [66], and perceptions [67].

Numerous studies [68] [69] show that the safety climate forms a core part of safety culture. Safety culture studies have been much focusing on the organization level [70], not just within contractors [71] but also other stakeholders [2]. Modeling safety culture can be found in various existing studies [72] [73]. Much work has addressed the relationships among safety climate, safety culture, and safety performance. For instance, Teo and Feng [74] found that safety climate impacted safety culture in terms of psychological, situational/environmental, and behavioral aspects, and the assessment of safety climate could forecast safety culture, which could further influence safety performance [75].

However, most existing studies [4] [76] on safety climate and safety culture have been set on the context of a specific country, with limited extending the framework for cross-country validation or international comparison. Nevertheless, it is an essential issue of implementing safety practices in international construction projects [77] and sharing the safety experience crossing countries. Patel and Jha [78] developed an ANN-based model to predict the safety climate in the Indian construction sector. However, it needs to focus on particular types of projects.

4. Conclusions

This paper represents the results of a scientometric analysis of ongoing research on safety in construction. Further mapping of the different research areas is done using a scientific mapping approach providing brief details about studies conducted and future scope of study in respective research areas. These proposed directions for future work could benefit to the academic community and industry practitioners in enhancing safety performance and improving site employees' health and wellbeing. The methodology of the study, the scientometric analysis, was carried out using 382 journal articles indexed by the WoS published from 2010 to 2019. This overall review explored by this study confirms that research in construction safety has a lot of scope in the future. And, it is an application in the industry that can help in improving the safety of the construction site. However, it should be pointed out that the current review is limited to the selected literature sample published in WoS, and only English journal articles were included. More, used data was collected almost one year ago. Recently many new publications would be added in the WoS databases, which are not part of this study. It might have potentially excluded some latest software and studies published in other languages or other types of documents such as trade magazines. However, outcomes of this study are very helpful to authors to determine the contents for construction safety manual which is a scope of the project sponsored by NHAI New Delhi.

Acknowledgement

Authors thank to the National Highway Authority of India (NHAI) New Delhi for sponsoring the project – the preparation state of art report (SoR) for construction safety manual. This study is a part of this project.

Disclosures

Free Access to this article is sponsored by SARL ALPHA CRISTO INDUSTRIAL.

References

1. Patel DA, Jha KN. Structural equation modeling for relationship-based determinants of safety performance in construction projects. Journal of management in engineering. 2016 Nov 1;32(6):05016017.
2. Wu C, Wang F, Zou PX, Fang D. How safety leadership works among owners, contractors and subcontractors in construction projects. International journal of project management. 2016 Jul 1;34(5):789-805.
3. Liu W, Zhao T, Zhou W, Tang J. Safety risk factors of metro tunnel construction in China: an integrated study with EFA and SEM. Safety science. 2018 Jun 1;105:98-113.
4. Chen Q, Jin R. Multilevel safety culture and climate survey for assessing new safety program. Journal of Construction Engineering and Management. 2013 Jul 1;139(7):805-17.
5. Rau PL, Liao PC, Guo Z, Zheng J, Jing B. Personality factors and safety attitudes predict safety behavior and accidents in elevator workers. International journal of occupational safety and ergonomics. 2018 Aug 7:1-9.
6. Cheung WF, Lin TH, Lin YC. A real-time construction safety monitoring system for hazardous gas integrating wireless sensor network and building information modeling technologies. Sensors. 2018 Feb;18(2):436.
7. Zhao X. A scientometric review of global BIM research: Analysis and visualization. Automation in Construction. 2017 Aug 1;80:37-47.
8. Jin R, Gao S, Cheshmehzangi A, Aboagye-Nimo E. A holistic review of off-site construction literature published between 2008 and 2018. Journal of Cleaner Production. 2018 Nov 20;202:1202-19.
9. Fang Y, Yin J, Wu B. Climate change and tourism: A scientometric analysis using CiteSpace. Journal of Sustainable Tourism. 2018 Jan 2;26(1):108-26.
10. Hosseini MR, Martek I, Zavadskas EK, Aibinu AA, Arashpour M, Chileshe N. Critical evaluation of off-site

construction research: A Scientometric analysis. Automation in Construction. 2018 Mar 1;87:235-47.

11. Lee PC, Su HN. Investigating the structure of regional innovation system research through keyword co-occurrence and social network analysis. Innovation. 2010 Apr 1;12(1):26-40.

12. Choe S, Leite F. Construction safety planning: Site-specific temporal and spatial information integration. Automation in Construction. 2017 Dec 1;84:335-44.

13. Malekitabar H, Ardeshir A, Sebt MH, Stouffs R. Construction safety risk drivers: A BIM approach. Safety Science. 2016 Feb 1;82:445-55.

14. Chen F, Liu Y. Innovation performance study on the construction safety of urban subway engineering based on bayesian network: a case study of BIM innovation project. Journal of Applied Science and Engineering. 2015 Sep;18(3):233-44.

15. Zhang S, Sulankivi K, Kiviniemi M, Romo I, Eastman CM, Teizer J. BIM-based fall hazard identification and prevention in construction safety planning. Safety science. 2015 Feb 1;72:31-45.

16. Li H, Lu M, Chan G, Skitmore M. Proactive training system for safe and efficient precast installation. Automation in Construction. 2015 Jan 1;49:163-74.

17. Chi HL, Chai J, Wu C, Zhu J, Wang X, Liu C. Scaffolding progress monitoring of LNG plant maintenance project using BIM and image processing technologies. In2017 International Conference on Research and Innovation in Information Systems (ICRIIS) 2017 Jul 16 (pp. 1-6). IEEE.

18. Shen X, Marks E. Near-miss information visualization tool in BIM for construction safety. Journal of construction engineering and management. 2016 Apr 1;142(4):04015100.

19. Pedro A, Le QT, Park CS. Framework for integrating safety into construction methods education through interactive virtual reality. Journal of professional issues in engineering education and practice. 2016 Apr 1;142(2):04015011.

20. Perlman A, Sacks R, Barak R. Hazard recognition and risk perception in construction. Safety science. 2014 Apr 1;64:22-31.

21. Sacks R, Whyte J, Swissa D, Raviv G, Zhou W, Shapira A. Safety by design: dialogues between designers and builders using virtual reality. Construction Management and Economics. 2015 Jan 2;33(1):55-72.

22. Zhou Y, Ding LY, Chen LJ. Application of 4D visualization technology for safety management in metro construction. Automation in Construction. 2013 Sep 1;34:25-36.

23. Cheng T, Teizer J. Real-time resource location data collection and visualization technology for construction safety and activity monitoring applications. Automation in construction. 2013 Sep 1;34:3-15.

24. Aguilar GE, Hewage KN. IT based system for construction safety management and monitoring: C-RTICS2. Automation in Construction. 2013 Nov 1;35:217-28.

25. Zou PX, Lun P, Cipolla D, Mohamed S. Cloud-based safety information and communication system in infrastructure construction. Safety Science. 2017 Oct 1;98:50-69.

26. Teo AL, Ofori G, Tjandra IK, Kim H. Design for safety: theoretical framework of the safety aspect of BIM system to determine the safety index. Construction Economics and Building. 2016;16(4):1.

27. Yi W, Wang S. Mixed-integer linear programming on work-rest schedule design for construction sites in hot weather. Computer-Aided Civil and Infrastructure Engineering. 2017 May;32(5):429-39.

28. Han Z, Feng X, Guo Z, Niu S, Ren L. Flourishing bioinspired antifogging materials with superwettability: progresses and challenges. Advanced Materials. 2018 Mar;30(13):1704652.

29. Yi W, Chan AP. Effects of heat stress on construction labor productivity in Hong Kong: a case study of rebar workers. International journal of environmental research and public health. 2017 Sep;14(9):1055.

30. Park J, Marks E, Cho YK, Suryanto W. Performance test of wireless technologies for personnel and equipment proximity sensing in work zones. Journal of Construction Engineering and Management. 2016 Jan 1;142(1):04015049.

31. Suo Q, Zhang D. Investigation and identification of factors affecting migrating peasant workers' usage of safety footwear in the Chinese construction industry. International journal of occupational safety and ergonomics. 2017 Jul 3;23(3):424-30.

32. Chen Q, Jin R. A comparison of subgroup construction workers' perceptions of a safety program. Safety science. 2015 Apr 1;74:15-26.

33. Choudhry RM, Fang D. Why operatives engage in unsafe work behavior: Investigating factors on construction sites. Safety science. 2008 Apr 1;46(4):566-84.

34. Guo BH, Yiu TW, González VA. Does company size matter? Validation of an integrative model of safety behavior across small and large construction companies. Journal of safety research. 2018 Feb 1;64:73-81.

35. Guo BH, Goh YM, Wong KL. A system dynamics view of a behavior-based safety program in the construction industry. Safety science. 2018 Apr 1;104:202-15.

36. Winge S, Albrechtsen E, Mostue BA. Causal factors and connections in construction accidents. Safety science. 2019 Feb 1;112:130-41.

37. Li H, Lu M, Hsu SC, Gray M, Huang T. Proactive behavior-based safety management for construction safety improvement. Safety science. 2015 Jun 1;75:107-17.

38. Chen WT, Wang CW, Lu ST, Pan NH. THE IMPACT OF SAFETY CULTURE ON SAFETY PERFORMANCE-A CASE STUDY OF TAIWAN'S CONSTRUCTION INDUSTRY. International Journal of Organizational Innovation (Online). 2018 Jul 1;11(1):1-5.

39. Aksan N, Sager L, Hacker S, Lester B, Dawson J, Rizzo M, Ebe K, Foley J. Individual differences in cognitive functioning predict effectiveness of a heads-up lane departure warning for younger and older drivers. Accident Analysis & Prevention. 2017 Feb 1;99:171-83.

40. Ly A, Boehm U, Heathcote A, Turner BM, Forstmann B, Marsman M, Matzke D. A flexible and efficient hierarchical Bayesian approach to the exploration of individual differences in cognitive-model-based neuroscience. Computational models of brain and behavior. 2017 Nov 29:467-80.

41. Fang D, Zhao C, Zhang M. A cognitive model of construction workers' unsafe behaviors. Journal of Construction Engineering and Management. 2016 Sep 1;142(9):04016039.

42. Abudayyeh O, Fredericks TK, Butt SE, Shaar A. An investigation of management's commitment to construction safety. International Journal of Project Management. 2006 Feb 1;24(2):167-74.

43. Chen Q, Jin R. Safety4Site commitment to enhance jobsite safety management and performance. Journal of Construction Engineering and Management. 2012 Apr 1;138(4):509-19.

44. Huang X, Hinze J. Owner’s role in construction safety. Journal of construction engineering and management. 2006 Feb;132(2):164-73.

45. Shahbodaghlou F, Haven R. A model for a quality safety program. Journal of Construction Education. 2000;5(3):260-71.

46. Bavafa A, Mahdiyar A, Marsono AK. Identifying and assessing the critical factors for effective implementation of safety programs in construction projects. Safety science. 2018 Jul 1;106:47-56.

47. Aksorn T, Hadikusumo BH. Critical success factors influencing safety program performance in Thai construction projects. Safety science. 2008 Apr 1;46(4):709-27.

48. Pereira E, Ahn S, Han S, Abourizk S. Identification and association of high-priority safety management system factors and accident precursors for proactive safety assessment and control. Journal of Management in Engineering. 2018 Jan 1;34(1):04017041.

49. Yiu NS, Sze NN, Chan DW. Implementation of safety management systems in Hong Kong construction industry–A safety practitioner's perspective. Journal of safety research. 2018 Feb 1;64:1-9.

50. Sandberg E, Albrechtsen E. A study of experience feedback from reported unwanted occurrences in a construction company. Safety science. 2018 Aug 1;107:46-54.

51. Lette A, Ambelu A, Getahun T, Mekonen S. A survey of work-related injuries among building construction workers in southwestern Ethiopia. International journal of industrial ergonomics. 2018 Nov 1;68:57-64.

52. Winge S, Albrechtsen E. Accident types and barrier failures in the construction industry. Safety science. 2018 Jun 1;105:158-66.

53. Manu P, Ankrah N, Proverbs D, Suresh S. An approach for determining the extent of contribution of construction project features to accident causation. Safety Science. 2010 Jul 1;48(6):687-92.

54. Jeelani I, Han K, Albert A. Automating and scaling personalized safety training using eye-tracking data. Automation in Construction. 2018 Sep 1;93:63-77.

55. Li Y, Guldenmund FW. Safety management systems: A broad overview of the literature. Safety Science. 2018 Mar 1;103:94-123.

56. Zhang S, Boukamp F, Teizer J. Ontology-based semantic modeling of construction safety knowledge: Towards automated safety planning for job hazard analysis (JHA). Automation in Construction. 2015 Apr 1;52:29-41.

57. Ardeshir A, Mohajeri M. Assessment of safety culture among job positions in high-rise construction: a hybrid fuzzy multi criteria decision-making (FMCDM) approach. International journal of injury control and safety promotion. 2018 Apr 3;25(2):195-206.

58. Chen Y, McCabe B, Hyatt D. A resilience safety climate model predicting construction safety performance. Safety science. 2018 Nov 1;109:434-45.

59. Alruqi WM, Hallowell MR, Techera U. Safety climate dimensions and their relationship to construction safety performance: A meta-analytic review. Safety science. 2018 Nov 1;109:165-73.

60. Newaz MT, Davis PR, Jefferies M, Pillay M. Developing a safety climate factor model in construction research and practice. Engineering, construction and architectural management. 2018 Jul 16.

61. Zhang S, Yan J, Hu Q, Wang J, Tian T, Chao J, Wang M. Integrated NMR and FE-SEM methods for pore structure characterization of Shahejie shale from the Dongying Depression, Bohai Bay Basin. Marine and Petroleum Geology. 2019 Feb 1;100:85-94.

62. Zahoor H, Chan AP, Utama WP, Gao R, Zafar I. Modeling the relationship between safety climate and safety performance in a developing construction industry: a cross-cultural validation study. International journal of environmental research and public health. 2017 Apr;14(4):351.

63. Gao R, Chan AP, Utama WP, Zahoor H. Multilevel safety climate and safety performance in the construction industry: Development and validation of a top-down mechanism. International journal of environmental research and public health. 2016 Nov;13(11):1100.

64. Zhang S, Shi X, Wu C. Measuring the effects of external factor on leadership safety behavior: Case study of mine enterprises in China. Safety science. 2017 Mar 1;93:241-55.

65. Jiang Z, Le H, Gollan PJ. Cultural intelligence and voice behavior among migrant workers: the mediating role of leader–member exchange. The International Journal of Human Resource Management. 2018 Mar 9;29(5):1082-112.

66. Xia N, Griffin MA, Wang X, Liu X, Wang D. Is there agreement between worker self and supervisor assessment of worker safety performance? An examination in the construction industry. Journal of safety research. 2018 Jun 1;65:29-37.

67. Stiehl E, Forst L. Safety climate among nontraditional workers in construction: arguing for a focus on construed external safety image. NEW SOLUTIONS: A Journal of Environmental and Occupational Health Policy. 2018 May;28(1):33-54.

68. Guldenmund FW. The nature of safety culture: a review of theory and research. Safety science. 2000 Feb 1;34(1-3):215-57.

69. Marquardt N, Gades R, Robelski S. Implicit social cognition and safety culture. Human Factors and Ergonomics in Manufacturing & Service Industries. 2012 May;22(3):213-34.

70. Goncalves Filho AP, Waterson P. Maturity models and safety culture: A critical review. Safety science. 2018 Jun 1;105:192-211.

71. Karakhan AA, Rajendran S, Gambatese J, Nnaji C. Measuring and evaluating safety maturity of construction contractors: Multicriteria decision-making approach. Journal of Construction Engineering and Management. 2018 Jul 1;144(7):04018054.

72. Koch C. From crew to country? Local and national construction safety cultures in Denmark. Construction management and economics. 2013 Jun 1;31(6):691-703.

73. Trinh MT, Feng Y, Jin X. Conceptual model for developing resilient safety culture in the construction environment. Journal of Construction Engineering and Management. 2018 Jul 1;144(7):06018003.

74. Teo EA, Feng Y. The role of safety climate in predicting safety culture on construction sites. Architectural Science Review. 2009 Mar 1;52(1):5-16.

75. Choudhry RM, Fang D, Lingard H. Measuring safety climate of a construction company. Journal of construction Engineering and Management. 2009 Sep;135(9):890-9.

76. Zahoor H, Chan AP, Utama WP, Gao R, Zafar I. Modeling the relationship between safety climate and safety performance in a developing construction industry: a cross-cultural validation study. International journal of environmental research and public health. 2017 Apr;14(4):351.

77. Gao R, Chan AP, Lyu S, Zahoor H, Utama WP. Investigating the difficulties of implementing safety practices in international construction projects. Safety science. 2018 Oct 1;108:39-47.

78. Patel DA, Jha KN. Prediction of Safety Climate through a Neural Network. In Construction Research Congress 2014: Construction in a Global Network 2014 (pp. 1861-1870).