A Review of Research Topics of Safety Management Systems

Chenggong Guo¹, Feng Jiang², Tao Chen³* and Ying Li³

¹State Grid Jiangsu Electric Power Co., Ltd., Nanjing, Jiangsu, 210024, China
²State Grid Xuzhou Power Supply Company, Xuzhou, Jiangsu, 221005, China
³School of Engineering & Technology, China University of Geosciences-Beijing, Beijing, 100083, China

*Corresponding author’s e-mail: 2002180091@cugb.edu.cn

Abstract. Safety management systems (SMSs) is a systematic safety management method, which is widely used and researched all over the world. This article reviews the current literature of safety management systems, summarizes and analyzes eight important research topics at the theoretical level, practical level, and standard level, including analysis of the connotation and extension, effectiveness analysis, integration of a safety management system and other systems, steps and content of construction, evaluation, comparison and selection of standards. Furthermore, based on the above analysis results and the current status of the application of safety management systems in China, two recommendations on important research directions are proposed. The research indicates that in order to improve the application effect of safety management systems in Chinese enterprises, we should concentrate on the basic theoretical research. Three questions need to be answered urgently at this stage: "What is a safety management system (SMS)?", "Why does it fail?" and "How to improve?".

1. Introduction

Safety management plays a huge role in preventing accidents and ensuring the smooth development of enterprise production activities. Since the occurrence of accidents such as Chernobyl and Piper Alpha, safety management has entered the third new historical stage after technical factors and human factors[1]. In this period, people have begun to perceive safety management from a systematic perspective, and safety management systems has gradually become the focus of attention in the academic and practical circles[2].

With the continuous deepening of SMSs research, we need to systematically review and analyze relevant literature. There have been studies involved in this work. Li[3] described SMSs from five core aspects through a broad overview of the literature: the definition, evolution, model, purpose and common elements. Corinne[4] explored the historical reasons for the emergence of SMSs from multiple dimensions, e.g. academic, insurance, supervision, and society. However, there are only a few scholars discussing what topics are included in the research field of SMSs. To this end, this article aims to fill this gap. We will first take a look at the distribution of research topics of SMSs. Then, we will introduce and comment each topic. Finally, we will propose some research directions based on the application of SMSs in China.

2. Research topics of safety management systems

A simple three-level level can be used to understand the current research status of literature review in safety management systems, namely the theoretical level (TL), the practical level (PL) and the standard
level (SL). We proceed from these three dimensions to conduct a literature review. Eight research topics were finally confirmed, as shown on the left side of Figure 1.

![Figure 1. Distribution of research topics on three levels of safety management systems.](image)

2.1. Theoretical level

2.1.1. Analysis of the connotation and extension of SMSs. In this topic, researchers mainly conduct qualitative analysis on the connotation and extension of the concept of a safety management system from the perspectives of system[5], macro and micro[6], process[7], function, control, compliance, history[3], theory and practice[8], etc., the main goal of which is to better understand the safety management system. As early as 1973, Kysor defined some characteristics shared by all SMSs from the perspective of risk management: a/ a definition of the organizational structure that needs to be established for managing safety; b/ analysis of operational risks; c/ a definition of a safety assurance process (including the definition and implementation of risk control measures) to maintain the risk at an acceptable level; d/ the risk communication process. McDonald[9] explored the connection between safety culture and SMSs. Furthermore, some qualitative models based on specific aspect were established. At present, the commonly used models include STAMP[10], Hale’s SMS framework[11], HFACS[12], Socio-technical model[13], Waring’s SMS model and Phoenix[14], etc.

2.1.2. Effectiveness analysis. Scholars also concern whether a safety management system is really effective in the production activities of enterprises. Qualitative or quantitative methods are used to verify the effectiveness, and three attitudes and opinions are formed, including support, neutrality and questioning(opposition). The proponents have provide statistically significant empirical evidence to emphasize that an SMS can bring better health and safety performance to enterprises[15-16]. The neutrals have remark that most studies on the effectiveness of safety management system interventions have moderate method limitations, and make an conclusion: the positive results shown in the published, peer-reviewed literature are not enough to make recommendations either support or oppose an SMS[17]. The main concerns of researchers who hold a skeptical attitude are the usefulness and cost of an SMS for small and medium-sized enterprises[18], the formalism of the certification system, and so on. Some
of them even have used harsh criticisms to describe SMSs, for example “paper tigers” [19]. Fortunately, there are also some rational skeptics who have been committed to exploring the reasons why SMSs is not applicable (failure)[20-21] and corresponding solutions[22-24]. For example, the literature[20] studied the fundamental causes why the safety management system is not fit Chinese industrial practice, including inadequate self-management mechanism, poor practical ground, and insufficient employee involvement.

2.2. Standards level

2.2.1. Comparison. Since the 1970s, standards, guidelines, and manuals of SMSs with different forms (ISO45001, PSM, ILO-OSH, HSG 65, SMS of Civil Aviation, DuPont's safety management system, etc.) have been developed in various fields by related organizations at the international and national levels, as well as some large international companies. Different versions of SMSs have a certain degree of similarities or differences in the background, theoretical basis, scope of application, elements, and management/evaluation methods. To explore the common or unique advantages of these systems, comparative analysis is a feasible method. Many researchers[25-26] have made such attempts and come to some conclusions that can be used for reference by companies.

2.2.2. Selection of standards. When companies intend to build up a safety management system, they will often choose a suitable international, national, industry or corporate safety management system (standard) as the basis for establishment. How to define and measure "suitable" for organizations? This is a complex decision-making problem that only a few researchers care about. Zhang[27] made this attempt. The author constructed an evaluation index system containing four dimensions of economy, technology, resources and objectives, and used AHP (analytical hierarchy process) and the fuzzy comprehensive evaluation method, with the aim of choosing the best safety management system (standard) for enterprises.

2.3. Practical level

2.3.1. Integration of an SMS and other systems. There are often multiple independent systems within an enterprise, such as a safety management system, an environmental management system (EMS), and a quality management system (QMS). Work efficiency may be affected and costs may become high, mainly because these systems are running at the same time, and resources such as human, material, and financial resources are reused[28]. In order to improve this phenomenon, the viewpoint of combining these systems with different management objectives in an enterprise into a comprehensive system has been supported by scholars and companies. Concepts, methods and technologies are also developed on a practical level and applied to the integration between different SMSs. Literature[29] is one of the representative results. The author discussed two ways of integration: a/ the introduction of individual systems, and then the integration of the initially separated systems; b/ the development and implementation of an integrated management system, integrated from the very beginning. The author also designed a model and method for implementing integrated management system (IMS) based on risk analysis, covering QMS, SMS and EMS.

2.3.2. Steps and content of construction. This part of the research content mainly introduces the main steps and content of the construction and implementation of an SMS, including understanding of the organization and its context, understanding of the needs and expectations of workers and other interested parties, determination of the scope of the system, leadership and worker participation, plan, support, operation, performance evaluation and improvement. It also refers to issues that should be paid attention to, for example, safety management procedures should be closely linked to the production activities of the companies[30].
2.3.3. Implementation path. System theory allows us to know that a system (safety management system) is an organic whole composed of several elements according to a certain structure with specific safety functions. Elements and structure have a dialectical and unified relationship. For this reason, some scholars have proposed that the implementation of a safety management system should adhere to systematic thinking, establish the relationship between the various variables in the system, and find the key success factors (elements) that affect the implementation of the system. Managers will benefit from this clear relationship when formulating implementation measures (paths) of the system. Researchers on this topic are more inclined to use quantitative methods. Decision Making Trial and Evaluation Laboratory (DEMATEL) method and Grey Relational Analysis (GRA)[31], Interpretive Structural Modeling Approach and MICMAC[32] are usually used. Based on many research results, the key success factors for reaching a consensus mainly include organization and responsibilities, safety policies, safety culture, risk management, communication, and safety investment.

2.3.4. Evaluation. Whether it is occupational health and safety management system (ISO45001, OSHAS18001) or the health, safety and environmental management system (HSE), they all put forward the requirements of the management system, but did not propose specific criteria of performance measurement. For organizations, although it is urgent to monitor the performance of the system to achieve continuous improvement, there is no measurement technology/method that can be effectively referenced by official standards. Research of evaluation technology starts from this. At present, development of a multidimensional scale based on the indicator system[33-34] are the most extensive research hotspots.

3. Suggestions on the research direction of safety management systems
Although the concept of SMSs has become popular, many studies have shown that in China, safety management systems established in accordance with international standards has not brought expected results in practice of organizations. These systems are usually abandoned by companies after a period of operation. The great structural adjustment of the safety management system of China Southern Power Grid Company and Sinopec Group in China is a good evidence. Faced with this phenomenon, what should we do? Based on the above analysis results and the current status of the application of SMSs in China, two recommendations on key research directions at present are proposed:

1) In various definitions and descriptions of safety management systems, we find that scholars’ analytical positions are relatively scattered. A research result also shows that there is no consensus on what an SMS is and the corresponding scope[17]. In practice, it is difficult for leaders and employees in companies to understand the safety management system, let alone participate effectively. To this end, we need to synthesize the views of what a safety management system is, and focus on distinguishing the type of system structure (process-oriented safety management system represented by ISO 45001, function-oriented safety management system represented by civil aviation SMS, etc.), and analyse its corresponding characteristics and methods.

2) It is unwise to emphasize whether a safety management system is beneficial to health and safety, as scholars[19] believe. We should admit that the safety management system is only a "vase" in most enterprises, not only did not improve the internal safety performance, but only increased the maintenance effort and cost. What we need to do is to actively explore the root cause of the inapplicability (failure) of SMSs and the corresponding solution.

4. Conclusions
In recent years, safety management systems has experienced more and more dissemination among companies in different industries, and has gradually become one of the hot spots in the research field of modern safety management. Through systematic review of relevant literature, this article draws the following conclusions:

1) The research topics of safety management systems can be divided from the theoretical, practical and standard levels. Specifically, it contains eight topics. The theoretical level focuses on analysis of the
connotation & extension and effectiveness analysis. The practical level includes integration of an SMS and other systems, steps and content of construction, implementation path and evaluation. The standard level highlights comparison and selection of standards. What needs to be emphasized is that the research on different topics is not completely carried out independently. The division of the research topics of SMSs in this article is mainly to let readers know the main research purpose of the researcher.

2) At present, if we want to improve the application effect of SMSs in Chinese enterprises, we should focus on three questions: "What is SMSs?" (What versions are there, and what are the advantages and disadvantages of the corresponding methods), "Why does it fail?" and "How to improve?". This requires us to pay attention to the basic theoretical research of SMSs.

Acknowledgments
This research was funded by Science and Technology Project of State Grid Corporation of China, grant number WBS: 1400-201957282A-0-0-00. The project’s title is Research on the construction of state grid safety management system.

References
[1] International Civil Aviation Organization (ICAO). (2013) Safety Management Manual (SMM) (AN/474). ICAO, Montreal.
[2] Luo, Y., Huang, X.F., Xu, M. (2016) Exploration on development and trend of scientific management on work safety. Journal of Safety Science and Technology, 12: 5-11.
[3] Li, Y.L., Guldenmund, F.W. (2018) Safety management systems: A broad overview of the literature. Safety Science, 103: 94-123.
[4] Corinne, B. (2021) Safety science: A situated science: An exploration through the lens of Safety Management Systems. Safety Science, 135.
[5] Zhang, L. (2010) The application of system approach in SMS construction (I). China Civil Aviation, 2: 19-21.
[6] Du, C.Y., Wang, Z.H., Du, C.F., Song, C.Y. (2007) On the Necessity of Establishing Coal Mine Intrinsic Safety Management System. Safety in Coal Mines, 38: 90-93.
[7] Huang, Y.J. (2011) Study of occupational health and safety management system based on process approach. Journal of Safety Science and Technology, 7: 197-202.
[8] Yorio, P.L., Willmer, D.R., Moore, S.M. (2015) Health and safety management systems through a multilevel and strategic management perspective: Theoretical and empirical considerations. Safety Science, 72: 221-228.
[9] McDonald, N., Corrigan, S., Daly, C., Cromie, S. (2000) Safety management systems and safety culture in aircraft maintenance organisations. Safety Science, 34: 151-176.
[10] Kazaras, K., Kontogiannis, T., Kirtyopoulos, K. (2014) Proactive assessment of breaches of safety constraints and causal organizational breakdowns in complex systems: A joint STAMP–VSM framework for safety assessment. Safety Science, 62: 233-247.
[11] Hale, A.R., Heming, B.H.J., Carthey, J., Kirwan, B. (1997) Modelling of safety management systems. Safety Science, 26: 121-140.
[12] Wiegmann, D.A., Shappell, S.A. (2001) Human error analysis of commercial aviation accidents: application of the Human Factors Analysis and Classification System(HFACS). Aviation, Space, and Environmental Medicine, 72: 1006-1016.
[13] Duijm, N.J. (2009) Safety-barrier diagrams as a safety management tool. Reliability Engineering and System Safety, 94: 332-341.
[14] Ekanem, N.J., Mosleh, A., Shen, S.H. (2016) Phoenix – A model-based Human Reliability Analysis methodology: Qualitative Analysis Procedure. Reliability Engineering & System Safety, 145: 301-315.
[15] Bottani, E., Monica, L., Vignali, G. (2008) Safety management systems: Performance differences between adopters and non-adopters. Safety Science, 47: 155-162.
[16] Iraj, M., Mojtaba, K., Mansour, M., Rostam, G., Yadollah, H., Alireza, S. (2017) Evaluation of the Quality of Occupational Health and Safety Management Systems Based on Key Performance Indicators in Certified Organizations. Safety and health at work, 8: 156-161.

[17] Robson, L.S., Clarke, J.A., Cullen, K., Bielecky, A., Severin, C., Bigelow, P.L., Irvin, E., Culyer, A., Mahood, Q. (2007) The effectiveness of occupational health and safety management system interventions: a systematic review. Safety Science, 45: 329–353.

[18] Arocena, P. (2010) An empirical analysis of the effectiveness of occupational health and safety management systems in SMEs. International Small Business Journal, 28(4):398-419.

[19] Hasle, P. (2011) Editorial: Occupational Health and Safety Management Systems: Issues and challenges. Safety Science, 49: 961-963.

[20] Fan, Y.X., Fu, G., Zhu, Y.W., Wang, X. (2015) A review of establishment and development of safety management system. China Safety Science Journal, 25: 3-9.

[21] Zhang, W., Cao, C.X., Wang, Y.M., Chen, X. (2016) Exploration on the failure cause of construction safety management system. Journal of Civil Engineering and Management, 33: 67-73.

[22] Makin, A. M., Winder, C. (2008) A new conceptual framework to improve the application of occupational health and safety management systems. Safety Science, 46: 935-948.

[23] Kennedy, R., Kirwan, B. (1998) Development of a Hazard and Operability-based method for identifying safety management vulnerabilities in high risk systems. Safety Science, 30: 249-274.

[24] Silva, S.L.C.d., Amaral, F.G. (2019) Critical factors of success and barriers to the implementation of occupational health and safety management systems: A systematic review of literature. Safety Science, 117: 123-132.

[25] Miao, J.M., Feng, Z.B., Zhou, X.Q. (2008) Comparative study on the standard modes of enterprise safety management system. China Safety Science Journal, 18: 62-67.

[26] Jiang, F., Guo, C.G., Wu, Y., Pei, J.J. (2020) Comparative Study on Safety Management System. In: The 8th International Symposium on Project Management, China (ISPM2020). Beijing. pp. 1269-1274.

[27] Zhang, S., Shi, X.Z., Huang, G.H. (2010) Choosing the best scheme of safety management system based on AHP and fuzzy comprehensive evaluation method. Journal of Safety and Environment, 10: 221-226.

[28] Liu, H., Luo, Y., Wang, Y.X. (2008) Study on integrative management system of dangerous chemicals enterprises safety standardization and OHSMS. Modern Chemical Industry, 28: 81-85.

[29] Labodová, A. (2004) Implementing integrated management systems using a risk analysis based approach. Journal of Cleaner Production, 12: 571-580.

[30] Duan, M., Wang, Q.Q., Yan, L. (2010) Discussion on issues of running OHSMS. China Safety Science Journal, 10: 221-226.

[31] Min, G.L., Duanmu, J.S., Gao, J.G., Zhang, B. (2015) Research on safety management system for aviation maintenance based on fuzzy DEMATEL. China Safety Science Journal, 25: 145-149.

[32] Rajaprasad, S.V.S., Chalapathi, P.V. (2015) Factors Influencing Implementation of OHSAS 18001 in Indian Construction Organizations: Interpretive Structural Modeling Approach. Safety and Health at Work, 6: 200-205.

[33] Chen, Q., Wen, H., Chen, B. (2011) OHSMS Performance Evaluation Based on Two-tuple Linguistic Information. China Safety Science Journal, 21: 156-161.

[34] Fernández-Muñiz, B., Montes-Peón, J.M., Vázquez-Ordás, C.J. (2007) Safety management system: Development and validation of a multidimensional scale. Journal of Loss Prevention in the Process Industries, 20: 52-68.