

A TAXONOMIC REVIEW OF THE APPLICATION OF SAFETY MANAGEMENT SYSTEMS IN CONSTRUCTION

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Abstract

The construction industry is one of the industries considered with the highest accident rates over the world because of its high risk and fast changing work nature (Tam, 2004). Construction safety has been perceived as one of key research areas in recent 20 years. Safety management system (SMS) was introduced in the construction industry in 1980s which aimed at reducing the number of injury cases, eliminating harmful conditions to workers and preventing materials damage at work. Content analysis was applied to review the previous relevant research papers and analyze the findings regarding the topic of various safety management systems adopted in the construction industry. The aim of this paper is to investigate and compare the research findings on safety management systems which had been implemented in the construction industry worldwide. Key features under safety management systems including the success factors, perceived benefits and potential difficulties will also be examined in order to identify the existing research gaps and corresponding research opportunities through this critical taxonomic review study.

Key words: *safety management systems, construction industry, taxonomic review*

1 INTRODUCTION

Safety management system (SMS) was introduced in the construction industry in 1980s which aimed at reducing the number of injury cases, eliminating harmful conditions to workers and preventing materials damage at work. Research studies found safety management systems particularly important in accident prevention and reduction through the development and implementation of proper and consistent safety management process or program of planning, education/training, and safety inspection (Chan and Hyeon, 2013; Sawacha et al., 1999; Wilson, 2000).

With reference to the accident rate as one of the key performance indicators of safety management systems, there were less continuous improvement in the construction industry over the past few years. In response to this, content analysis was adopted to examine the published research studies regarding the safety management systems used in the construction industry and to suggest the existing research gaps to fill in and make continuous improvement to the safety performance of the construction industry in future.

The aim of the paper is to investigate and compare the research findings on safety management systems which had been implemented in the construction industry. It provides a critical taxonomic review of the key features of the research designs, benefits and difficulties, success factors of implementation and maintenance of safety management systems. It will be valuable to explore and compare research designs and findings to identify the current research gaps or some possible recommendations for improving the effectiveness of safety management systems conducive to better safety performance of the construction industry.

2 RESEARCH METHODOLOGY

Content analysis was used to review the previous relevant research papers and analyze the findings regarding the topic of safety management systems adopted in the construction industry worldwide. The critical review of previous research studies offers valuable information and useful guidance in the selection of target journal papers (Ke et al., 2009; Li et al., 2014; Tang et al., 2010; Xue et al., 2010).

Two stages of analysis were adopted in the study including the desktop literature search on relevant papers and the in-depth examination on the contents of the selected target papers.

2.1 Step one- Review of previous journal papers

Journal papers on the topic of safety management systems were obtained through systematic searching in Scopus database, which covers the main peer-refereed journals in the management and engineering fields (Hong and Chan, 2014; Kyei and Chan, 2015) until July 2015. Scopus search engine was adopted in reviewing the literature of similar review studies particularly in construction management topics (Hong et al., 2011; Hong and Chan 2014; Kyei and Chan, 2015; Yi and Wang, 2013; Yuan and Shen, 2011). Furthermore, the accuracy and coverage of Scopus database is found better than other search engines such as Google Scholar, PubMed and Web of Science (Falagas et al., 2008; Kyei and Chan, 2015). Articles containing the most-searched terms ‘safety management’ and ‘safety management system’ in the ‘title/abstract/keyword’ were considered for review in this research. There are totally 134 academic papers matching the research terms but unmatching the proposed research topic in this study. The searched literature is required to be further filtered and refined by reviewing the contents. By reviewing the abstract, introduction and methodology of each article, the main industry sectors of the articles are grouped as follows: general, construction, aviation, food, nuclear, shipping, chemical/ oil and gas and manufacturing. As this study focuses on the construction industry, there are 66 papers based on the construction sector or applicable to all sectors. Then after further review of the abstract, introduction and background of each article, 54 out of 66 papers focused on topics relating the safety management systems that are applicable for the construction industry.

2.2 Step two – Examination on the contents of the target papers

This review is to analyse the trend and identify the existing research gaps of research on construction safety management systems based on the selected literature, so it may not include all the academic articles relating the topic of safety management systems in the construction industry. Considering the 54 target papers shown in the reference list, the following information will be analysed: (1) Year of publication, (2) Name of publication, (3) Number of authors, (4) Country or region of research focus, (5) Methodology adopted, (6) Key findings on perceived benefits, potential difficulties and critical success factors of implementation of SMS.

For literature coding for each target paper, the main coding sources are heading, abstract, introduction, objectives and methodology. Other remaining sessions will be coded when incomplete information is available for analysis.

2.3 Review on relevant publications

In order to have a comprehensive documentary review of the safety management systems in the construction industry, reliable information and publications published by the relevant professional journal publishers and government departments were compared to supplement the findings as mentioned in Section 2.2.

3 FINDINGS AND DISCUSSIONS

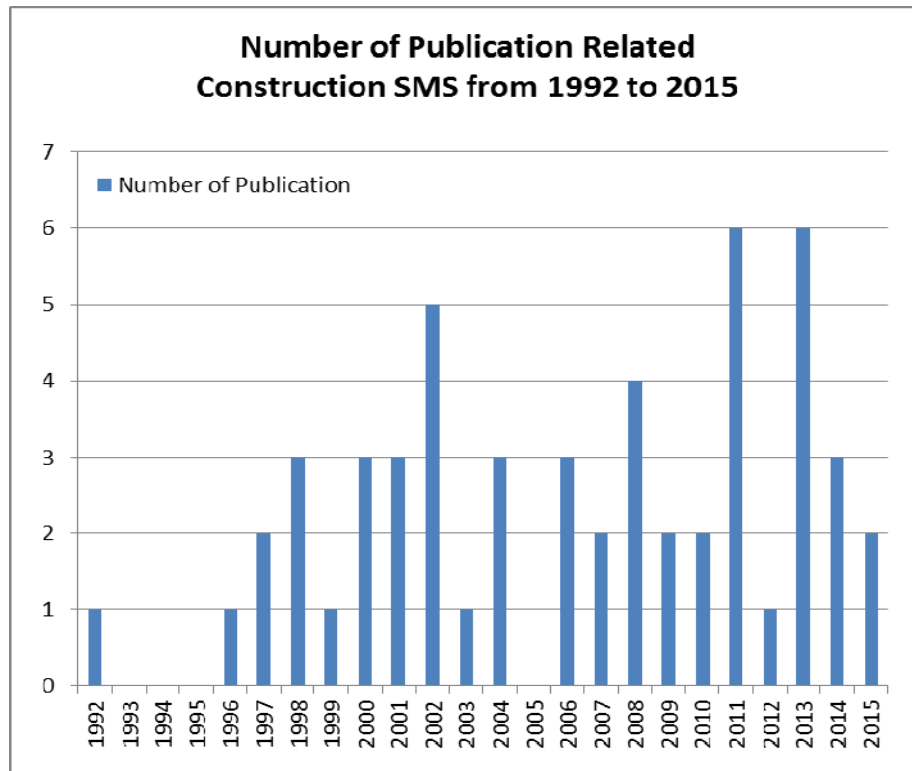
3.1 Research Design

3.1.1 Year of publication

There was no significant increase of construction SMS-related publications with reference to the statistics available in Figure 1. Safety management system was considered as one of the key topics that needs to continuously review and study starting from year 1996. It was believed that with the

consideration of high-risk nature and accident rates of the construction industry, there is a constant demand for the researchers to review their safety management systems.

Figure 1. The Number of SMS-related Articles Published from 1992 to 2015



3.1.2 Name of publication

All 54 published articles were extracted from the 21 journals as shown in Table 1. There are 19 articles extracted from Safety Science, 6 articles extracted from Construction Management and Economics, 4 articles extracted from Journal of Construction Engineering and Management. These three journals contributed to 54% of the articles being reviewed in this study.

Table 1. List of Journals Involving Topics on Construction SMS

	Name of Publication	Number of articles
1	Accident Analysis and Prevention	1
2	American Industrial Hygiene Association Journal	1
3	Applied Ergonomics	1
4	Automation in Construction	3
5	Building and Economics	1
6	Construction Management and Economics	6
7	Environmental Science and Policy	1
8	IPM (Information Sciences SM15)	1
9	Industrial Health	1

10	Industrial Management and Data Systems	1
11	International Journal of Production Research	2
12	Journal of Civil Engineering and Management	2
13	Journal of Construction Engineering and Management	4
14	Journal of Hazardous Materials	1
15	Journal of Loss Prevention in the Process Industries	2
16	Journal of Professional Issues in Engineering Education and Practice	1
17	Journal of Management in Engineering	1
18	Journal of Safety Research	2
19	Professional Safety	2
20	Managerial Auditing Journal	1
21	Safety Science	19
	Total	54

In order to understand the importance of construction safety being considered by these three named journals, i.e. Safety Science, Construction Management and Economics and Journal of Construction Engineering and Management, the scope of these three journals and their previous 5-year publications from June 2010 to May 2015 was reviewed. It was found that construction safety was considered as one of the key interests of research area. The objectives and number of construction safety related publications are summarized in Table 2.

3.1.3 Number of authors

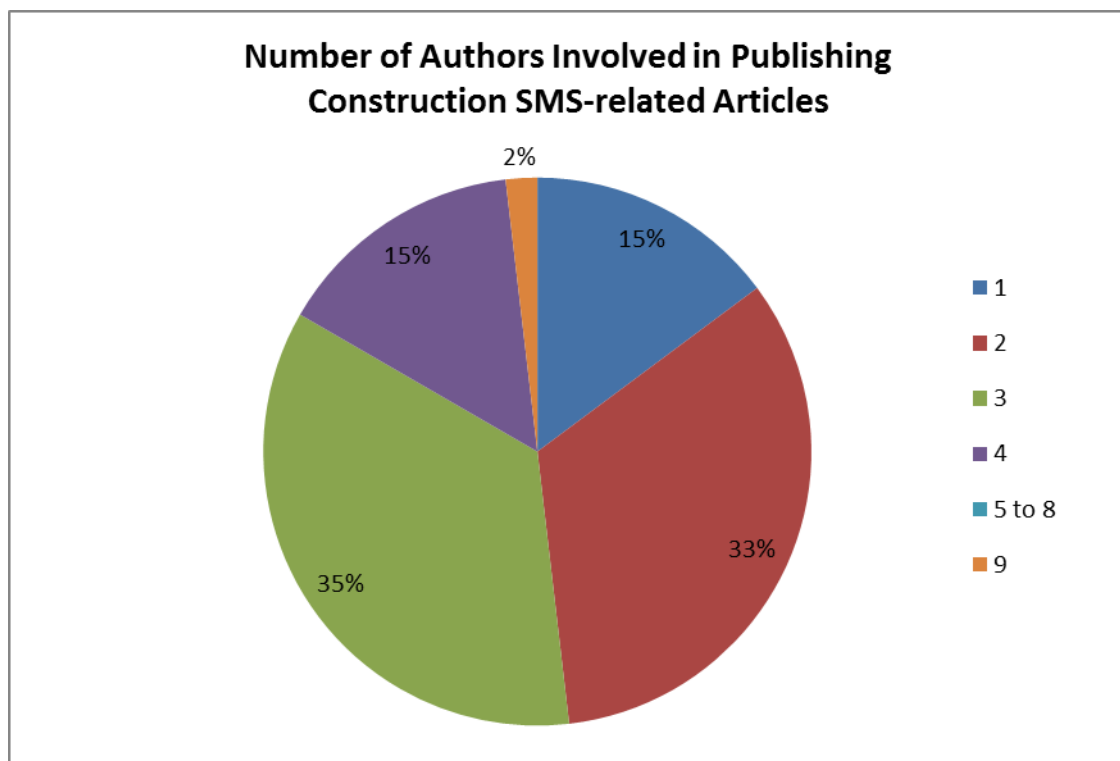
With reference to Figure 2, 33% and 35% of articles were contributed by two and three researchers. For those articles with one author only, these articles were found mainly adopting the method of desktop literature review only. All the articles were contributed by not more than 4 researchers, except one article contributed by 9 researchers. That article was an in-depth review study on SMS for all industry sectors contributed by 9 researchers.

Table 2. Scope and Weighting of Construction Safety Research Studies in Safety Science, Construction Management and Economics and Journal of Construction Engineering and Management from June 2010 to May 2015

Name of Journal	Scope of the Journal	Construction Safety Related Papers (Contributed % of the Corresponding Journal)
Safety Science	Safety Science covers the original research in multidisciplinary with the major focuses on the science and technology of human and industrial safety. It extends to the topics relating the physics, engineering and social aspects of safety; risk assessment and management and its communication; the management and control of safety and its effectiveness; human	264 (24.4%)

	behavior, safety laws and standards, safety inspection, etc.	
Construction Management and Economics	Construction Management and Economics covers original research concerning the management and economics of activity in the construction industry. It extends to various disciplines relating the construction sector, such as the concept of construction, the design, procurement and through-life management of the entire range of construction services.	41 (11.4%)
Journal of Construction Engineering and Management	Journal of Construction Engineering and Management covers the original research science of construction engineering, harmonize construction practices with design theories, and further education and research in construction engineering and management. Topics include, but are not limited to, the following: construction material handling, equipment, production planning, specifications, scheduling, estimating, cost control, quality control, labor productivity, inspection, contract administration, construction management, computer applications, and environmental concerns.	66 (11.1%)

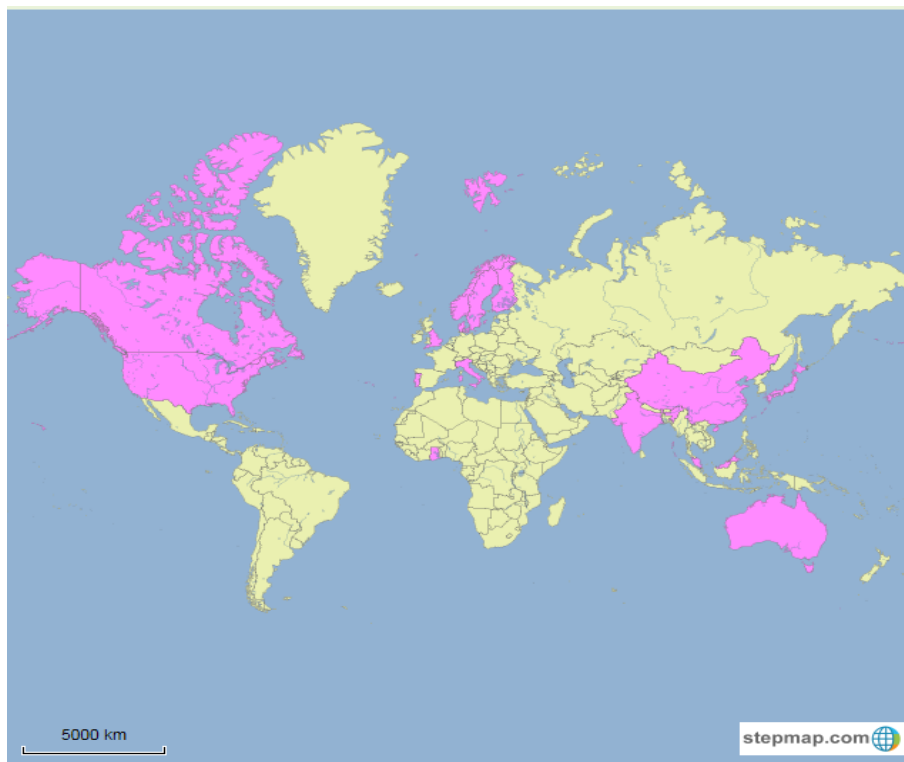
Figure 2. Number of Authors in Publishing the Construction SMS-related Articles



3.1.4 Country or region of research focus

All the selected construction SMS related articles were published in 19 countries/regions as shown in pink colour on the map (Figure 3). Hong Kong, the United Kingdom and Singapore, China (excluding Hong Kong) published 4 or more articles relating SMS of the construction industry. These former three countries/regions were found the compulsory implementation of SMS or relevant health and safety policies starting from 1999. China (excluding Hong Kong) also introduced the national OHSMS Guidance Committee by the State Commission of Economy and Trade which develops OHSMS Trial Standard, supervises accreditation and manages safety auditor registration (Kogi, 2002).

Figure 3. Map Showing the Countries/ Regions of the Published Articles in this Study



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3.1.5 Methodology adopted

Both qualitative and quantitative methods were commonly adopted in doing research on construction safety management systems. There are totally 33 articles involving qualitative methods and 28 articles involving quantitative methods in collecting the data for the selected articles. 7 out of 54 articles showed the use of a mixed method, which included the use of both qualitative and quantitative methods in research methodologies.

For qualitative studies, 11 out of 28 articles applied the use of content analysis by reviewing the relevant documents and articles carried by previous authors. 7 out of 28 of them applied case study methodology with questions setting to collect both qualitative and quantitative data from target respondents within the selected sample companies. 10 out of 28 of them applied case studies, which included the application of interviews with open-ended questions, action research and documentation review, to collect the qualitative data so as to achieve the stated objectives or tested the hypothesis, model or computer-based system as a trial study.

For quantitative studies, questionnaire survey with structured questions was mostly adopted in collecting the quantitative data for further analysis. The response rates ranged from 11.4% to 32%,

except one study that led by the governmental department with 72% response rate. All collected data were used as statistical analysis purpose. Five statistical tools of data analysis, including (1) factor analysis, (2) estimation of the mean value, (3) ranking cases, (4) one-way variance (ANOVA), (5) Spearman's rank correlation, were commonly analysed by the Statistical Package for Social Sciences (SPSS) program. The Structural Equation Modelling (SEM) and neural network analysis were used for testing of hypothesis since 2013.

3.2 Potential benefits, Potential Difficulties and Success Factors of SMS

With reference to Tables 3, 4 and 5, there are totally 21 perceived benefits, 16 potential difficulties and 23 critical success factors in the implementation of SMS in the construction industry. Having fewer accidents or injury cases and less accident induced cost were considered as one of mostly agreed benefits of executing SMS in construction. Another mostly agreed benefit was the positive impact on the safety audit in terms of the quantitative scores (Table 3).

Table 3. Perceived Benefits of SMS in Construction Industry

Perceived benefits of Safety Management Systems in Construction Industry		Rafiq, Dongping,	Beatriz, José, &	Lynda et al., 2007	Bunn et al., 2001	L.S. Robson et	Pearse, 2002	LaMontagen et	Alan & Vincent,	Daniel Podgórski,	Kazutaka, 2002	Matthijs, Eric,	Chuanjing &	Fernandez et al.,	Smallman &	Yang & David,	
1	Fewer near miss and reported accidents	√															
2	Lower accident rates		√	√	√												
3	Easy to follow with systematic framework (Plan, Do, Check, Act)								√	√							
4	Effective top-down communication																
5	Clear safety organization with defined responsibilities and accountabilities of key personnel										√						
6	Better safety culture				√												
7	Safer working conditions	√															

8	Improved employees' morale															
9	Public attention to occupational safety and health (OSH)									√						
10	Enhanced productivity			√		√										
11	Reduced materials damage		√								√					
12	Reduced cost of accidents		√	√	√											
13	Improved organizational competitiveness		√									√	√			
14	Improved economic / financial performance or profitability		√													
15	Increased employees' OSH awareness	√														
16	Reduced harm to workers		√													
17	Positive change in the scores from a quantitative audit			√	√		√	√								
18	Better company's public image and reputation											√		√		
19	Improvement in accident investigation and analysis															√
20	Improvement in emergency preparedness															√
21	Increased support for OSH training and information									√						

Potential difficulties identified in construction SMS were mainly related to the personnel involving the SMS. For instance, subcontractors did not coordinate with the project team in carrying out the SMS; insufficient safety knowledge, poor attitude and resistance by the project team; insufficient commitment on Occupational Safety and Health (OSH) by senior management (Table 4).

Table 4. Potential difficulties of SMS in Construction Industry

Potential Difficulties of Safety Management Systems in Construction Industry		Kazutaka, 2002	Stephen & Bob, 2002	Chuanjing & Steve, 2014	Yang & David, 2013	Daniel Podgórski, 2015	Nongiba, Alistair, & Andrew, 2010
1	Different goals expected by project team members	√	√				
2	Obstruction by sub-contractors						
3	Insufficient safety knowledge or risk concepts for project team	√					
4	Resistance to change by project team or sub-contractors			√			
5	Insufficient resources	√			√		
6	Too narrowly focused	√	√			√	
7	Isolated in the hands of safety professionals who assume all responsibilities for safety issues		√				
8	Tight project schedule			√	√		
9	Tight management control				√		
10	Paperwork-intensive operation					√	
11	Poor OSH attitude by project team	√					√
12	Non-availability of construction equipment						
13	Lack of momentum for continuous improvement		√	√			
14	No common safety language developed (especially in multi-sites organization)		√				
15	Insufficient commitment to OSH issues				√		

With reference to Tables 5 and 6, strong management commitment on OSH was considered as the most important success factor for the development, implementation and maintenance of SMS and the most critical characteristic of construction site with outstanding safety performance in local construction industry. Cost spent on safety issues and the quality and competence of safety managers (or safety-in-charge of the project) were also considered as the important critical factors contributing to the success of SMS.

Table 5. Critical Success Factors of SMS in Construction Industry

Critical Success Factors of Safety Management System (SMS) in Construction Industry		Rafiq et al., 2008	Beatriz et al., 2009	Lynda et al., 2007	Alsop & LeConteur,	Bunn et al., 2001	Edkins, 1998	Yassi, 1998	LaMontagne et al.,	Yang & David, 2013	Beatriz et al., 2007	Stephen & Bob,	Alan & Vincent,	Zubaidah, Samad, &	Lu & Yan, 2010	Eleonora, Luigi, &	S. Mohamed, 1999	Krause, 1993	Charles & Steven,	Redinger & Lerrine,	Di, Chris, Vincent,	
1	Senior management commitment	√	√	√	√	√	√	√	√	√	√											
2	Adequate manpower			√							√	√										
3	Cost spent on safety issues	√		√							√	√					√	√				
4	Provision of adequate time											√										
5	Safety leadership of the senior management													√	√							
6	Subcontractor selection								√													
7	Safety Incentives			√								√										
8	Safety manager's qualities			√												√	√					
9	Personal competency of the safety manager			√								√					√					
10	Training and education of project manager															√	√					
11	Safety behaviours of the project manager													√								
12	Safety organization	√															√					
13	Key staff's safety awareness	√														√						
14	Teamwork			√																		
15	Frequent staff group meetings															√						
16	Good communication system															√			√	√		
17	Safety culture of the project																					√

safety performance. Safety managers (safety-in-charge) are considered to be one of the key personnel responsible and accountable for SMS. His quality and competency were vital to influence the performance of SMS or site safety performance. These two particular areas were also recommended to be quantified in order to better justify the performance of the safety management systems, together with the construction site safety performance.

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