TEHRAN UNIVERSITY OF MEDICAL SCIENCES

IJOH INTERNATIONAL JOURNAL OF OCCUPATIONAL HYGIENE
Copyright © 2008 by Iranian Occupational Health Association (IOHA)
2008-5435/14/63-1-8

IRANIAN OCCUPATIONAL HEALTH ASSOCIATION IOHA

ORIGINAL ARTICLE

The Integrated Methodology of Health, Safety, and Environmental (HSE) Risk Assessment based on the Project Management Body of Knowledge (PMBOK)

MOHSEN SADEGHI YARANDI[1], EHSAN JAFARNIA[2], SAMIRA GHIYASI[2], AHMAD SOLTANZADEH[3*]

[1] *Department of Occupational Health Engineering, School of Public Health, Tehran University of Medical Sciences, Tehran, Iran*

[2] *Department of Environmental Engineering, Central Tehran Branch, Islamic Azad University, Tehran, Iran*
[3] *Department of Occupational Safety & Health Engineering, Faculty of Health, Research Center for Environmental Pollutants, Qom University of Medical Sciences, Qom, Iran*

Received May 22, 2020; Revised August 14, 2020; Accepted August 27, 2020

This paper is available on-line at *http://ijoh.tums.ac.ir*

ABSTRACT

One of the major challenges in construction projects is the mismatch of risk concepts in HSE and project management as a result of negligence in HSE matters on the part of project managers. The current study was aimed to clarify the risk management principle as an important domain of PMBOK and to present an integrated HSE risk assessment tool according to PMBOK. This cross-sectional study was done to analyze 21 risks of the four types of HSE risks using PMBOK in one of the biggest construction projects in 2019. The risk matrix including likelihood and severity was the basis of this integrated risk assessment model. The severity of consequences includes four types of impacts (impacts on project's costs, timing, quality and human force), and also the weighting coefficient of each dimension was applied based on the importance of each consequence. The results showed that among 21 identified sources of risk, nine sources were at a high level (3rd level) and only one source was at a low level (1st level). Moreover, it has been founded that among the four types of HSE risks including work breakdown structure, project costs, quality, and emergency situations in construction projects are at the highest level. In cases that there was no money allocated for hiring supervisor, expert, and HSE officer considering different project phases has been evaluated as the highest source of danger. The current study provided an appropriate alternative for commonly used risk assessment methods in construction projects because it made a whole change in projects managers' and HSE members' points of view and presented a new attitude toward risk identification, consequence analysis, and the usage of PMBOK project management standard in the risk management process in construction projects.

KEYWORDS: *Risk Assessment; HSE; Construction Project; PMBOK*

INTRODUCTION

Nowadays one of the major reasons for economic development and growth in a society is the advances in civil and construction projects and the establishment of necessary infrastructures in a community. The concept of the Project Management Body of Knowledge (PMBOK) was emerged to provide the required guidelines in project management by describing the methods and processes in order to successfully generate the required output within the agreed time, cost, and quality standard [1]. PMBOK draws attention to nine major domains of management including integration, timing, expenses, quality, human force, communication, maintenance, and risk management [2]. According to Steven Pender's findings, PMBOK can make a big difference in the domain of project management. Since risk management closely related to the major basics of a project such as a cost, time, and quality. So, it can be effective in the profitability of projects and goal achievement [3].

Construction is one of the most hazardous, dangerous, and eventful industries [4-5]. The existence of occupational accidents in construction projects including “fall from the height and slip, throw objects, and friction” not only causes direct and indirect costs and unfortunate social consequences, but also results in legal proceedings, organizational credibility loss, a decline in project quality, and etc. Therefore, organizations with a relatively low incidence have more efficiency [6-7]. Consequently, health, safety, and environment (HSE) risk assessments are effectively used to identify and discover crisis points in projects. Moreover, identification and classification of crisis points based on the risk level have an effective role in the presentation of suitable solutions, for instance, preventive actions and providing safe conditions for construction activities [8-9]. Previous studies showed that using the project management models and combining them with safety concepts in construction projects can reduce safety risk levels and provide a better description of existing hazards in working environments [10-11].

Corresponding author: Ahmad Soltanzadeh
E-mail: soltanzadeh.ahmad@gmail.com

A lot of research regarding HSE risk assessment has been carried out which is resulted in more than ten different risk models with their own advantages and disadvantages [12-15]. Surprisingly, despite the different risk assessment methods, no one of them was unable to show a slight change in the prevention of risks happening in construction projects or a sensible reduction in construction accidents. Thus, to minimize this dilemma, in the present study, we tried to create a common language between the project manager, site supervisor, and other units with the HSE unit.

Having considered these issues, this study has been designed and carried out with the purposes of clarification of risk management principle as an important domain of PMBOK and presentation of an integrated HSE risk assessment tool according to PMBOK.

MATERIALS AND METHODS

This cross-sectional study was designed based on an analytical-descriptive framework in one of the biggest construction projects in the west of Tehran, Iran in 2019. The number of workers working on the studied project was 1100 people.

Project Management Institute (PMI) under the guidance of PMBOK defined risk management planning, risk identification, qualitative & quantitative analysis of risk, responses to risk, monitoring, and risk control for a six-phase-project risk management process [16]. Considering the purposes of this study, only three initial steps including planning, identification, and qualitative analysis have been presented.

First Step; Planning and developing a risk management algorithm:

The tools and techniques used in this phase included: continuous scheduled meetings with the project manager, HSE manager, risk experts and units involved in the field of implementation such as electricity, mechanics and key stakeholders. The output of this stage including the content of the HSE resource management program were as follows:

Published online: September 30, 2020

The methodology, role and responsibility of each member of the meeting in HSE risk management, HSE risk management budgeting and the frequency of the resource management process in the project, how to performed quantitative and qualitative risk assessment, the structure of the risk assessment matrix, HSE risk management report format and the necessary follow-ups until the implementation of the HSE risk management system.

In this phase, the structure and format of the risk management process and all the cases in which there may be differences between the HSE risk management team were discussed, and on this basis, all aspects of the HSE risk management process were presented in an integrated manner [17].

Second Step; Identification of risk's sources:

This step includes identification of HSE risks in the construction project. A new method for HSE risk identification has been introduced in this study; as a result, the risk identification process is started from the perspective of the project management process, and risks were divided into 11 categories: HSE risks related to (1) project's work breakdown structure (WBS), (2) project's costs and equipment, (3) project's quality, (4) emergency response, (5) HSE management, (6) human resources, (7) design phase, (8) operation phase, (9) legal actions, (10) changes in technology or instructions, and (11) communication. Since a wide range of categories exist, only four of the most important risk's categories were studied that including HSE risks related to (1) project's WBS, (2) project's costs and equipment, (3) project's quality, and (4) emergencies [18, 19].

HSE Risks in the WBS of the project:

WBS negligence is one of the generally ignored risks in the risk management process which has a negative impact on project timing and ultimately leads to accidents. For example, according to the existing requirements, special training for working at heights is required considering their work amendments. So, it can be easily planned, if this issue is observed in the WBS of the project [18].

HSE Risks associated with project's costs:

Various studies showed that one of the root causes of accidents in the construction industry is the issue of investing in project safety. For example, the reluctance of managers to allocate funds in the implementation of the fall protection system and the implementation of vertical and horizontal lifelines in the installation of steel structures [19].

HSE Risks related to project's quality:

Improving the quality of materials, equipment, machinery and even personal protective equipment will have a great impact on reducing the volume of accidents. For example, one of the main causes of accidents in milling and sawing is the low quality stone plate usage, which causes accidents [18].

HSE Risks related to emergency situations:

HSE risks in this category can bankrupt any organization. In contrast, proper management of these risks can significantly reduce the damage to the organization. Among the significant risks mentioned in this section is the non-implementation of the emergency response plan (ERP) [18].

Third Step; Qualitative Risk Assessment:

This step includes a qualitative assessment of identified risks. Risk assessment depends on two factors: the likelihood of occurrence and the impact on the project's goals. In the present study four basic items were used to measure consequences resulting from risks: (1) the imposition of financial expenses on projects, (2) the impact on project's timing, (3) the impact on the quality of project task completion, and (4) human force importance.

Because of the inequality of aforementioned factors impacts, a weighing factor (WF) is set for each of the 4 items by HSE experts so that the obtained Risk Index (RI) can be assumed close to reality. The severity factor is based on the weighing factor of each item. The weighing factors including

Published online: September 30, 2020

impact on the project's costs (cost), impact on the project's timing (timing), impact on the quality of the project-task completion (quality), and impact on the human force (human force) were set 0.47, 0.41, 0.37, and 0.9, respectively.

According to ISO 14971, risk is the combination of likelihood and severity (consequence) [20]. In this study likelihood is ranging from 1 to 5, including; (1) unlikely, (2) seldom, (3) occasional, (4) likely, and (5) definite. Similarly, consequence is ranging from 1 to 5, including; (1) insignificant, (2) minor, (3) moderate, (4) critical, and (5) catastrophic.

As the consequence of each item is the product of total sum of severity items and their WF, the 1st, 2nd, 3rd, 4th and 5th level of consequences was related to final score of consequences 1-4, 5-8, 9-12, 13-15 and 16-19, respectively. To classify risk levels as a decision-making criterion, control actions and suggestions were used from one of the most common methods including (1) low-risk level (the green area), (2) medium-risk level (the yellow area), and (3) high-risk level (the red area) (21). Additionally, the risk matrix has been shown in Table 1.

Table 1. Risk matrix based on PMBOK approach

		Likelihood				
		1	2	3	4	5
Severity	1	1	2	3	4	5
	2	2	4	6	8	10
	3	3	6	9	12	15
	4	4	8	12	16	20
	5	5	10	15	20	25

RESULTS

In the identification step, 21 risk sources in four categories were identified (Tables 2 to 5). In the qualitative risk assessment stage, first the numerical value of the likelihood factor and then the items of intensity and weighting coefficients were determined and based on this, the risk index was calculated.

It was apparent from the analysis of five HSE risk sources within the project's WBS that four sources require heightened awareness and specific procedures (level 2), and one source can be managed by routine procedures (level 1) (table 2).

Table 2. Risk assessment results in the WBS of the Project

Risk Identification	Qualitative risk assessment							
		Severity						
Risk Source	Likelihood Level	Cost	Timing	Quality	Human Force	Severity score	Severity Level	Risk Index
1. Failure to set the time for periodic testing after recruitment (personnel working in high-risk places in WBS).	3	2	2	1	5	11.89	3	9
2. Failure to set the time to secure all workplaces before the start in WBS.	4	2	2	2	5	10.7	3	12
3. Failure to set the time for periodic testing after recruitment (personnel working in low-risk places in WBS).	2	2	1	1	2	8.48	3	6
4. Failure to set vocational training time related to working in height for all personnel working at height.	3	2	2	1	5	11.65	3	9
5. Lack of legal permission for disposal and, burying wastes from the municipality.	2	2	1	1	1	5.78	2	4

According to the assessment results of six risk sources related to the project costs and equipment (Table 3), four sources require immediate actions (level 3) and two sources require heightened awareness and specific procedures (level 2). The highest risk index related to project and equipment costs were related to late payment of employees' salaries causing occupational stress and the failure to focus on tasks and fail to provide safe standard equipment and machinery (crane, tower crane, lift truck, and high-risk devices) (RI=16).

Table 3. Project and equipment costs risk assessment

Risk Identification	Qualitative risk assessment							
		Severity						
Risk Source	Likelihood Level	Cost	Timing	Quality	Human Force	Severity score	Severity Level	Risk Index
1. Not allocating enough budget to provide standard personal protective equipment on the part of contactors						0.66		
2. Not implementing HSE improvement projects (implementation of horizontal and vertical life line system on a metal scaffold, the use of safety fuse for all electrical panels and etc.						3.1		6
3. Lack of allocation of money for Periodic examinations.						2.54		2
4. Late payment of employees' salaries causing occupational stress and the failure to focus on tasks.						3.27		6
5. Fail to implement safety-culture activities (encouragement, posters, training courses).						1.32		
6. Fail to provide safe standard equipment and machinery (crane, tower crane, lift truck, and high-risk devices).						3.27		6

Based on the findings of Table 4, four sources require heightened awareness and specific procedures (level 2), and two sources of quality-related risk include lack of maintenance schedule for machinery and the use of poor quality pipe, fastener, connector, and other components of scaffold (heavy scaffold) had the highest risk index and needed immediate control measures.

Table 4. Quality risk assessment

Risk Identification	Qualitative risk assessment							
		Severity						
Risk Source	Likelihood Level	Cost	Timing	Quality	Human Force	Severity score	Severity Level	Risk Index
1. Lack of personal protective equipment (except for the falling protective equipment).	3	2	2	1	3	9.76	3	9
2. Lack of falling protective equipment with the high quality.	4	2	2	1	5	11.56	3	12
3. Lack of maintenance schedule for machinery.	3	3	3	3	5	12.78	4	12
4. The use of poor quality pipe, fastener, connector, and other components of scaffold (heavy scaffold).	4	3	3	3	5	14.13	4	16
5. Lack of standard working platforms.	3	2	2	2	5	11.53	3	9
6. Fail to provide standard electrical devices, welding and cutting equipment.	4	2	2	2	5	11.24	3	12

The results of table 5 showed three sources including lack of first aid equipment (RI-12), lack of identification of emergencies in accordance with the project's situation (RI-16) and lack of suitable emergency reaction team (RI-12) demand priority control actions (level 3).

Table 5. Emergencies risk assessment

Risk Identification	Qualitative risk assessment							
		Severity						
Risk Source	Likelihood Level	Cost	Timing	Quality	Human Force	Severity score	Severity Level	Risk Index
1. Lack of first aid equipment						3.23		2
2. Lack of a safe place (muster points)						0.29		
3. Lack of identification of emergencies in accordance with the project's situation						2.57		6
4. Lack of suitable emergency reaction team						2.57		2

DISCUSSION

The findings have indicated that among the four types of risks, and 21 sources of risk, nine sources are at high risk which indicates high levels of safety risk in the studied construction project and has been matched with other studies [22]. HSE related accidents and risks in the construction industry have different consequences such as different types of injuries and diseases, disability, or even death, as well as many direct and indirect costs for related organizations and working groups [4, 23, 24]. Determining the various causes of occupational accidents and determining the importance of paying attention to these risks is one of the most important measures to improve the status of HSE in construction projects. Therefore, the role of the risk management process in identifying potential sources and assessing the resulting risk will be very important and sometimes vital. Analysis of such accidents has also shown that weakness in the process of risk assessment and control can be one of the basic and important causes of occupational accidents in construction projects [25].

However, some studies have indirectly addressed the training risks, repairs and maintenance risk, quality of personal protective equipment, improving the attitude and understanding of HSE supervisors, and the quality of equipment in accident prevention [6, 14, 26-28], studies that can assess the sources of project major risks from the perspective of project management are limited. These sources of risk can have significant human, economic, social, and even political consequences for large construction projects. On the other hand, this is the first time that a model is designed to assess the risks of four categories in a construction project, including HSE risks in WBS, project's costs, quality, and the reaction in emergencies, and 21 risk sources of these four category.

It should be noted that during the present study, the weight of risk from different sources of risk has been considered. However, in many previous studies, only two factors, likelihood and severity, were addressed. Furthermore, the results of some studies have shown that different factors affect the amount of HSE risk; HSE risks impact on the quality by Husin et. al. [14], HSE risks' impact on costs by John A. Gambatese et. al. [29], and HSE risks' impact on human force by Garrett et. al., [30] are the examples of such studies. Based on PMBOK project management standard, consequences of some parameters including the imposition of additional costs on the project, the impact on project's timing and quality, the credibility loss of the organization, human force importance, and human force injuries are not deniable in construction projects [18, 31]. Additionally, each parameter has different effects. For example, the impacts of accidents on human force are not the same as the impacts on quality. Thus, weighing factors are necessary to determine the importance of each parameter.

Analysis of five HSE risk sources within the project's WBS demonstrated that four sources require heightened awareness and specific procedures (level 2), and one source can be managed by routine procedures (level 1) (table 2). Findings showed that the highest risk index in this sector is related to the lack of proper planning to secure workplaces (RI-12) and also the lack of attention to the importance of training for working at height before the start of the project (RI-9). Previous studies have also shown that most accidents in the construction industry are related to people and equipment falling from heights [32].

According to the assessment results of six risk sources related to project costs and equipment (Table 3), four sources require immediate actions (level 3). The highest risk index related to the project and equipment costs were related to late payment of employees' salaries causing occupational stress and the failure to focus on tasks and fail to provide safe standard equipment and machinery (crane, tower crane, lift truck, and high-risk devices) (RI=16).

Based on the findings of Table 4, four sources require extra awareness and specific procedures (level 2), and two sources of quality-related risk include lack of maintenance schedule for machinery and the use of poor quality pipe, fastener, connector, and other components of scaffold (heavy scaffold) had the highest risk index and needed immediate control measures.

The cost is a significant risk assessment and risk prioritization factor based on the evaluated data. The safety precautions and risk assessment failure will impose large financial costs on the project, for example, the penalties resulting from non-compliance with HSE regulations, compensation, medical expenses, the rise in insurance rate, indirect costs due to low efficiency, damages to equipment, etc. [18]. A high-risk index can be due to the impact on the project's timing. The death of a major member of the project, the delay for his/her replacement, the delay for fixing and starting a new device, and long delays because of non-compliance with HSE regulation by authorities are some good examples of this category [28]. According to the findings and the results of other studies, the quality of the project is seriously affected by construction accidents [33]. Additionally, different consequences may affect the project whenever an accident happens for a simple worker, project manager, or the head manager.

The results of Table 5 showed that three sources need priority control actions (level 3) including lack of first aid equipment (RI-12), lack of identification of emergencies in accordance with the project's situation (RI-16), and lack of suitable emergency reaction team (RI-12). These findings highlighted the need to develop a comprehensive risk management algorithm tailored to the type of activities in the construction industry with a focus on accurate hazard identification and risk assessment.

One of the limitations of the present study was the time constraint for studying all dimensions of the PMBOK project management standard.

Despite the innovation in HSE risk assessment on the basis of PMBOK (including classification of risks and their sources according to project management approach in construction projects, making a new useful analysis method of consequence and severity of risk's sources, and show the importance of weighing factor in accordance with each evaluated parameters), researchers in future can investigate other different dimensions of PMBOK or assessment the risk source in accordance with other management standards like PRINCE2 and OPM3. Additionally, they can study the usage of this model in other projects to solve prioritized risks.

CONCLUSION

This study may provide an appropriate alternative to commonly used risk assessment methods in construction projects considering its major impact on the projects managers' and HSE members' points of view and presented a new attitude toward risk identification, consequence analysis, and the usage of PMBOK project management standard in the risk management process in construction projects. Therefore, the use of this integrated method for risk assessment of construction projects is suggested.

ACKNOWLEDGMENT

The authors are grateful of the head manager and all the personnel for their participations in the implementation of the studied construction project. Vice-Chancellor for Research and Technology of Qom University of Medical Sciences and Health Services partially supported this study by contract No. 971000.

CONFLICTS OF INTEREST

The authors declare no conflicts of interest.

REFERENCES

1. Abd Elhameed AT. Analyzing the Project Management Body of Knowledge (PMBOK) through theoretical lenses: A study to enhance the PMBOK through the project management theories. PM World Journal. 2018;6:1-31.
2. Snyder CS, editor A Guide to the Project Management Body of Knowledge: PMBOK Guide 2014: Project Management Institute.
3. Pender S. Managing incomplete knowledge: Why risk management is not sufficient. International Journal of Project Management. 2001;19(2):79-87.
4. Soltanzadeh A, Mohammadfam I, Moghimbeygi A, Ghiasvand R. Exploring causal factors on the severity rate of occupational accidents in construction worksites. International journal of civil engineering. 2017;15(7):959-65.
5. Mohammadfam I, Soltanzadeh A, Moghimbeigi A, Akbarzadeh M. Confirmatory factor analysis of occupational injuries: presenting an analytical tool. Trauma monthly. 2017;22(2).
6. Enshassi A, Mohamed S, Abushaban S. Factors affecting the performance of construction projects in the Gaza strip. Journal of Civil engineering and Management. 2009;15(3):269-80.
7. Ganbat T, Chong H-Y, Liao P-C, Wu Y-D. A Bibliometric Review on Risk Management and Building Information Modeling for International Construction. Advances in Civil Engineering. 2018;2018.
8. Soltanzadeh A, Mohammadfam I, Moghimbeigi A, Ghiasvand R. Key factors contributing to accident severity rate in construction industry in Iran: a regression modelling approach/Primjena regresijskog modela u analizi ključnih čimbenika koji pridonose težini nesreća u građevinskoj industriji u Iranu. Archives of Industrial Hygiene and Toxicology. 2016;67(1):47-53.
9. Zou PX, Sunindijo RY. Skills for managing safety risk, implementing safety task, and developing positive safety climate in construction project. Automation in Construction. 2013;34:92-100.
10. Jazayeri E, Dadi GB. Construction safety management systems and methods of safety performance measurement: A review. Journal of Safety Engineering. 2017;6(2):15-28.
11. Badri A, Gbodossou A, Nadeau S. Occupational health and safety risks: Towards the integration into project management. Safety science. 2012;50(2):190-8.
12. Verma H, Verma N. A Study on Risk Assessment and Safety Management in the Construction of High-Rise Buildings. 2017.
13. Simu K, editor Risk management on small projects. Nordic Conference on Construction Economics and Organsiation: 14/06/2007-15/06/2007; 2007: Luleå tekniska universitet.
14. Husin HN, Adnan H, Jusoff K. Management of safety for quality construction. Journal of Sustainable Development. 2009;1(3):41.
15. Banaitiene N, Banaitis A. Risk management in construction projects. Risk Management-Current Issues and Challenges: InTech; 2012.

16. Marcelino-Sádaba S, Pérez-Ezcurdia A, Lazcano AME, Villanueva P. Project risk management methodology for small firms. International journal of project management. 2014;32(2):327-40.
17. Raz T, Michael E. Use and benefits of tools for project risk management. International Journal of Project Management. 2001;19(1):9-17.
18. Zwikael O. The relative importance of the PMBOK® Guide's nine Knowledge Areas during project planning. Project Management Journal. 2009;40(4):94-103.
19. Aminbakhsh S, Gunduz M, Sonmez R. Safety risk assessment using analytic hierarchy process (AHP) during planning and budgeting of construction projects. Journal of safety research. 2013;46:99-105.
20. Catelani M, Ciani L, Diciotti S, Dori F, Giuntini M, editors. ISO 14971 as a methodological tool in the validation process of a RIS-PACS system. Medical Measurements and Applications Proceedings (MeMeA), 2011 IEEE International Workshop on; 2011: IEEE.
21. Aven T. On the new ISO guide on risk management terminology. Reliability engineering & System safety. 2011;96(7):719-26.
22. Sawacha E, Naoum S, Fong D. Factors affecting safety performance on construction sites. International Journal of Project Management. 1999;17(5):309-15.
23. Mohammadfam I, Soltanzadeh A, Moghimbeigi A, Akbarzadeh M. Modeling of individual and organizational factors affecting traumatic occupational injuries based on the structural equation modeling: a case study in large construction industries. Archives of trauma research. 2016;5(3).
24. Winge S, Albrechtsen E, Arnesen J. A comparative analysis of safety management and safety performance in twelve construction projects. Journal of safety research. 2019;71:139-52.
25. Mohammadfam I, Soltanzadeh A, Mahmoudi S, Moghimbeigi A. P154 Analytical modelling of occupational accidents' size using structural equation modelling approach (SEM); a field study in big construction industries. BMJ Publishing Group Ltd; 2016.
26. Soltanzadeh A, Mohammadfam I, Moghimbeygi A, Ghiasvand R. Exploring causal factors on the severity rate of occupational accidents in construction worksites. International journal of civil engineering. 2017:1-7.
27. Soltanzadeh A, Mohammadfam I, Mahmoudi S, Savareh BA, Arani AM. Analysis and forecasting the severity of construction accidents using artificial neural network. Safety Promotion and Injury Prevention. 2017;4(3):185-92.
28. Wang SQ, Dulaimi MF, Aguria MY. Risk management framework for construction projects in developing countries. Construction Management and Economics. 2004;22(3):237-52.
29. Gambatese JA, Behm M, Hinze JW. Viability of designing for construction worker safety. Journal of Construction Engineering and Management. 2005;131(9):1029-36.
30. Garrett J, Teizer J. Human factors analysis classification system relating to human error awareness taxonomy in construction safety. Journal of Construction Engineering and Management. 2009;135(8):754-63.
31. Soltanzadeh A, Mohammadfam I, Moghimbeigi A, Akbarzadeh M, Ghiasvand R. Key factors contributing to accident severity rate in construction industry in Iran: a regression modelling approach. Arhiv za higijenu rada i toksikologiju. 2016;67(1):47-53.
32. Kang Y, Siddiqui S, Suk SJ, Chi S, Kim C. Trends of fall accidents in the US construction industry. Journal of Construction Engineering and Management. 2017;143(8):04017043.
33. Hallowell MR, Gambatese JA. Activity-based safety risk quantification for concrete formwork construction. Journal of Construction Engineering and Management. 2009;135(10):990-8.