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Original Article

Do construction companies still consider the pandemic as a part of construction safety management?

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Abstract

Construction safety management has been affected by the COVID-19 pandemic. Though the pandemic is under control, some policies and regulations should remain to ensure safe work. This study examines key factors affecting construction safety in Thailand after the COVID-19 pandemic. The analytic hierarchy process (AHP) is used with five key construction safety factors: safety policy, human resources management, safety resources management, hazard and risk, and COVID-19 pandemic. The analysis results reveal that the "hazard and risk" and "safety policy" are crucial in enhancing construction safety, specifically in hazard identification and safety procedures. The construction companies should also ensure adequate safety equipment and provide new workers with job orientation and safety training. Some policies like work-from-home, bubble-and-seal, along with pandemic-related equipment, may be maintained to minimize safety risks and ensure company safety standards.

Keywords: AHP, construction safety management, COVID-19 pandemic, Thailand

1. Introduction

Construction sites can be hazardous, and accidents and injuries can occur without proper safety protocols. According to Maillard (2023), the construction industry is one of the most dangerous sectors in Thailand, holding the highest risk at 5.77**%** and resulting in over 4500 injuries and fatalities in 2021. Laws and regulations are established to protect workers and ensure site safety. Despite the laws, many construction-related accidents occur in Thailand. The COVID-19 pandemic has significantly impacted construction safety, and new measures have been initiated to ensure safe workplaces. For example, Oo and Techapeerapanich (2021) identified the impacts of the COVID-19 pandemic on Thai construction projects, including the shortage of material, the decrease in work efficiency, the expected increase in disputes, and safety concerns regarding virus spread. The results provide the contractors a better understanding of the impacts of pandemic on construction projects and guide ways for safe work during the pandemic. Almohassen, Alkhaldi, and Shaawat (2023) highlighted the need to prevent and control the infection of the workers and re-evaluate the existing safety programs to control the effects of the pandemic on sites in Saudi Arabia.

The COVID-19 pandemic forces the construction industry to revise and adjust the safety guidelines to prevent and minimize losses. For instance, Abdull Rahman, Kamaruding, Mohd Nusa, and Mohd Dzulkifli (2022) identified the feasibility of the new safety and health guidelines for the post-COVID-19 situation in the project job site in Malaysia. Isang and Ebiloma (2023) developed strategies to achieve sustainable project performance in the post-COVID-19 era in Nigeria's construction sector. Selleck, Cattani, and Hassall (2022) collected leading and lagging safety indicators in Australian construction sites and compared safety performance pre- and post-pandemic.

To effectively plan for construction safety management after the COVID-19 pandemic, it is vital to consider the pandemic's effects on construction safety and include those effects in the safety guidelines, if necessary, to minimize losses from possible recurrences. This study utilizes the AHP approach to identify and examine the importance weights of key factors affecting Thai construction safety after the COVID-19 pandemic. The research flow is in Figure 1.

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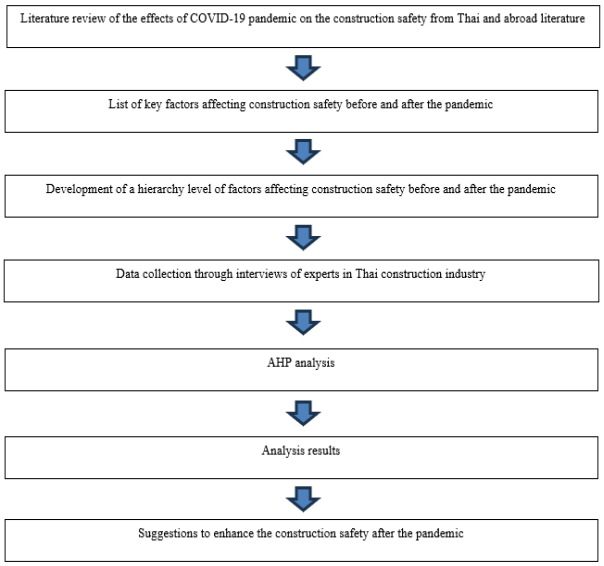

Figure 1. Research flow

2. Key Factors Affecting Construction Safety before and after the Pandemic

Construction safety related literature is reviewed to extract key factors affecting construction safety before and after the pandemic. For example, Khaday, Li, and Dorloh (2023) concluded key factors affecting the preventive behaviours among construction workers in Bangkok during the COVID-19 pandemic. Al-Saffar, Darwish, and Farrell (2023) examined factors with high-risk impact on the hospital's construction project in Iraq. Chinda (2024) gathered perceptions and practices of construction safety culture management by construction companies in Thailand during the COVID-19 pandemic utilizing five key factors: leadership, people, resources, policy and strategies, and processes.

This study summarizes construction safety related literature from the Scopus database to extract key factors affecting construction safety before and after the COVID-19 pandemic, Table 1. This database is widely used in many construction-related studies (Chinda, 2024; Jain, 2024; Obidjon, 2024). Four main factors are mostly cited in the construction safety literature: safety policy (POL), human resources management (HRM), safety resources management (SRM), and hazard and risk (HAZ) factors. In addition, the COVID-19 pandemic (COV) is crucial in construction safety and a main factor affecting construction safety management in the hierarchical model, Figure 2.

2.1 POL factor

Safety policy should be included in short- and long-term business goals for effective safety performance (Chinda, 2012). Othman *et al*. (2020) stated that safety policies and regulations are the foundation of safety management. They should be strictly enforced for efficient implementation. Two sub-factors associated with this factor include safety regulations and safety procedures. Safety regulations serve as a benchmark for the construction industry to ensure the safety of personnel and equipment. Compliance with regulations is vital to promote a safe work environment (Kolawole, Idris, & Mudashir, 2023). Safety procedures should be prioritized to ensure that standardized practices are followed.

2.2 HRM factor

Human resources are crucial for the construction sector, and the success of a company depends on skills, knowledge, and experiences of its employees. This study separates the HRM factor into management position and operation position sub-factors due to their roles and responsibilities. Management's support in safety activities creates a workplace safety culture. On the other hand, negative human factors, such as workload and peer pressure,

Table 1. Construction safety factors extracted from the literature

Factor	Definition
POL	Safety policies must be included in the companies' missions and visions.
HRM	Human resources, both management and operation levels, are crucial for a successful safety implementation.
SRM	Sufficient safety resources should be allocated to perform day-to-day activities safely.
HAZ	Proper safety management is required to reduce hazards and risks at work and minimize injuries and fatalities.
COV	The COVID-19 pandemic has long-term effects on safe work practices of the construction industry.

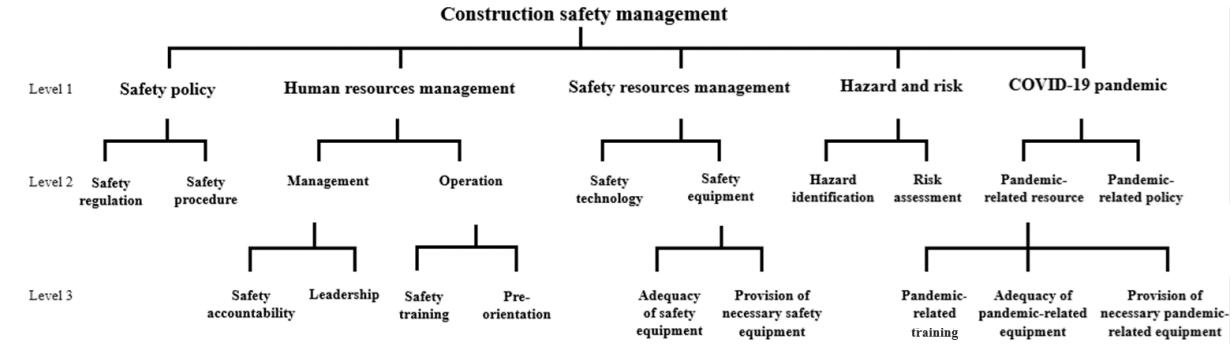

Figure 2. Hierarchical model of construction safety management

degrade the mental condition of the workers and impact the safety responses to unsafe acts (Rashid, Hadikusumo, & Chowdhury, 2023).

The management position sub-factor comprises two attributes: leadership and safety accountability. Ideal leadership has a positive impact on the success of construction safety management. Chinda (2012) mentioned that safety responsibilities must be assigned from top to bottom levels of authorities. Insufficient safety resources, poor safety commitment, and poor safety accountability are the main barriers to safety program implementation in the construction industry. The operation position sub-factor comprises safety training and pre-orientation on job details. Insufficient safety practices, inadequate safety training, dangerous work conditions, and outdated equipment are causes of accidents on sites (Chinda & Pongsayaporn, 2020). On-the-job training can improve workers' performance and quality. Pre-orientation is necessary, especially for new workers, to comprehend work procedures and potential safety hazards on sites.

2.3 SRM factor

This study separates the SRM factor into safety technology and safety equipment sub-factors. Huang, Wang, and Wu (2022) commented that safety researchers and professionals in the new era attach importance to the perspective of safety information and emerging technologies in safety management. Smart safety management integrates various emerging technologies, such as the safety monitoring system based on cyber-physical systems, safety warning systems, and information and communication technology to adjust real-time safety requirements in the workplace, thus reducing work accidents. The safety equipment sub-factor comprises two attributes: adequacy of safety equipment and provision of necessary safety equipment. Inadequate safety equipment and improper design are major causes of accidents and safety problems on construction sites (Chinda & Pongsayaporn, 2020). Necessary safety equipment should be included in existing acts and regulations to enhance safety awareness and safe work among workers.

2.4 HAZ factor

The HAZ factor is separated into two sub-factors: hazard identification and risk assessment. The hazard identification is one of the essential steps for construction safety management since most unmanageable risks are from unidentified hazards. It is critical in ensuring safety in construction projects. Assessing risks before accepting a job is essential to prevent accidents and mitigate hazards. Risk assessment is performed to quantify the risks and determine if the risk levels are acceptable or require the mechanisms to control them. Construction safety risk assessment measures personnel, management, environment, machinery, and equipment safety statuses. Sanni-Anibire, Mahmoud, and Hassanain (2020) developed a risk assessment approach to enhance the safety performance of construction projects and concluded that the falling of an object has the highest risk score, and excessive winds on the project site are the most significant cause.

2.5 COV factor

Disease protection should be integrated into safety and health policy during and after the COVID-19 pandemic to ensure the safety and health of employees. Safety resources, such as face masks and alcohol gel, should be provided even after the pandemic to ensure site safety standards. Workers should be educated and trained to protect themselves from contagious diseases (Chinda, 2024). The COVID-19 pandemic factor comprises two sub-factors: the pandemic-related policy and the pandemic-related resources. Simpeh and Amoah (2022) stated that most construction companies in South Africa have incorporated aspects of COVID-19 guidelines, such as site access, handling of COVID-19 cases, screening, and social distancing, into the site's health and safety policies. New safety policies, such as the entry screening, social distancing measures, quarantining infected or at-risk personnel, and mandated additional PPE for all personnel, may be used to reduce the spread of COVID-19 in a construction environment.

The pandemic-related resources sub-factor consists of three attributes, namely the pandemic-related training, the adequacy of pandemic-related equipment, and the provision of necessary pandemic-related equipment. Nnaji, Jin, and Karakhan (2022) suggested that construction companies develop an infectious disease training program that provides guidelines for implementing new COVID-19-related practices. The company should also have a temporary public medical facility, testing sites, pre-diagnostics and treatment, emergency medical transportation for COVID-19 patients, and sanitation supplies, such as surgical and respiratory masks and gloves, ventilators, touch-free thermometers, and gowns (Kolawole *et al*., 2023).

3. Research Methodology

3.1 The AHP method

The AHP is utilized in this study to determine key factors and their importance weights in construction safety management. This approach is a pairwise comparison method of measurement theory. It divides the problem into factors and arranges them into hierarchy levels. After that, each pair of factors is compared using the scales 1-9 (Table 2) to determine the most significant factors and choices (Ammarapala *et al*., 2018). The random index (RI) value is used to measure the consistency in the pairwise comparison completely (Table 3).

Table 2. AHP scale for pairwise comparison (Ammarapala *et al*., 2018)

Importance score	Definition
1	Equal importance between the two adjacent judgments
3	Moderate importance of one over another
5	Strong importance of one over another
7	Very strong importance of one over another
9	Extreme importance of one over another
2, 4, 6, 8	Intermediate values between the two adjacent judgments

Table 3. Acceptable RI values (Ammarapala *et al*., 2018)

Matrix size	Random consistency index (RI)
1	0
2	0
3	0.58
4	0.9
5	1.12

3.2 Data collection

Data used in the AHP analysis are collected from the interviews of seven experts in the construction industry. According to Melon, Beltran, and Cruz (2008), 6-12 experts are considered reliable for the interviews. They are in management positions, such as safety managers, project managers, and executives. The details are as follows.

- Interviewee#1 is a project manager in a large-sized construction company with 120 employees and $28.8 million in capital investment. The company specializes in road, bridge, and tunnel construction.
- Interviewee#2 is an executive in a large-sized construction company with over 2,000 employees and $31.7 million in capital investment. The company provides various services, including the design and construction of building and civil engineering projects, the design, fabrication, and erection of steel structures, and mechanical and electrical installations.
- Interviewee#3 is a professional safety officer in a large-sized construction company with over 2,000 employees and $31.7 million in capital investment. The company provides various services, including the design and construction of building and civil engineering projects, the design, fabrication, and erection of steel structures, and mechanical and electrical installations.
- Interviewee#4 is a construction manager in a large-sized construction company with 110 employees and $2.9 million in capital investment. The company specializes in full-cycle road construction, such as concrete roads and asphalt concrete roads, with affiliated companies for completed construction work, such as concrete pipes, cement piles, and asphalt.
- Interviewee#5 is the head of personnel section in a large-sized construction company with 200 employees and $0.72 million in capital investment. The company operates in the product distribution business and installs equipment for various systems in the construction industry.
- Interviewee#6 is a safety manager in a medium-sized construction company with 320 employees and $0.59 million in capital investment. The company specializes in construction and real estate development. Most of the projects are factories and warehouses.
- Interviewee#7 is a business process developer in a medium-sized construction company with over 200 employees and $2.9 million in capital investment. The company specializes in non-residential building construction.

Each interviewee is asked to provide the score of each pair of statements (Figure 2) using the sale 1–9. For example, suppose the interviewee considers the POL factor equal to the HRM factor in construction safety management. In that case, the scores of 1 are provided for both factors. In contrast, if the interviewee considers the “safety regulation” sub-factor as having very strong importance over the “safety procedure” sub-factor in the POL factor, then the score of 7 on the “safety regulation” side is selected. Further, if the interviewee considers the “safety procedure” as having very strong importance over the “safety regulation”, then the score of 7 on the “safety procedure” side is selected, Figure 3.

Level 1

Safety policy	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Human resources management
Safety policy	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Safety resources management
Safety policy	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Hazard and risk
Safety policy	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	COVID-19 pandemic
Human resources management	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Safety resources management
Human resources management	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Hazard and risk
Human resources management	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	COVID-19 pandemic
Safety resources management	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Hazard and risk
Safety resources management	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	COVID-19 pandemic
Hazard and risk	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	COVID-19 pandemic

Level 2

Safety regulation	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Safety procedure

Level 3

Pandemic-related training	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Adequacy of pandemic-related equipment
Pandemic-related training	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Provision of necessary pandemic-related equipment
Adequacy of pandemic-related equipment	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Provision of necessary pandemic-related equipment

Figure 3. Example of an AHP survey form

4. Results

Each interviewee is asked to provide the scores of 21 comparison statements (i.e., 10 pairs of factors, five pairs of sub-factors, and six pairs of attributes). The analysis results are checked with the RI values to accept or reject the results. For instance, the five key construction safety factors form a 5×5 matrix; of this, an RI value not exceeding 1.12 is required to accept the analysis results (Table 3). To gain the overall opinions of seven interviewees, the geometric mean is employed to finalize and normalize the weight of each factor, sub-factor, and attribute.

The results, Figure 4, show that the HAZ factor is the most crucial factor for construction safety management in Thailand. This is consistent with You, Sze, and Chan (2018) in that it is necessary to alleviate the hazards present in the workplace and decrease the risk of injuries and property damage. The "hazard identification" has a higher weight than the "risk assessment" sub-factors. Improving hazard identification enhances safety levels at construction sites. Unidentified hazards, in contrast, lead to a significant increase in site accidents. The "risk assessment", though obtaining less important weight than the "hazard identification", is still crucial as it becomes a critical task of the safety management system. However, it is a challenge to undertake a risk assessment on construction sites as the work nature of the industry is unique, highly hazardous, and quickly changing, and the workforce is highly dynamic.

The POL factor is the second most important factor in improving construction safety in Thailand. In the POL factor, the "safety procedures" is considered more important than the "safety regulations" sub-factors. To mitigate the risks, the company should enforce worksite safety policies, and the employees should clearly understand safety procedures, including hazard identification and risk assessment (Sooklamai, & Jiracheewanun, 2020).

The safety performance of the construction industry relies mainly on the effective allocation of safety resources. In the SRM factor, the concern should be more on the "safety equipment" rather than the "safety technology" sub-factors. Having the right safety equipment is key to ensuring the health and safety of workers on site. The adequate provision of safety equipment and PPEs are prerequisites for improved safety performance. Equipment should also be well-designed and suitable for jobs to minimize accidents and enhance safety performance (Chinda, 2012). Huang *et al*. (2022) commented that in the new era, safety professionals focus more on safety information and technologies in safety implementation. However, errors may occur if safety technology is used to manage safety only. Some safety decisions should still be made based on management's experiences with safety technology.

In the HRM factor, the management position is crucial in enhancing construction safety, as it receives a higher weight than the operation position. This may be because management is responsible for establishing safety policies and allocating the budget to support HRM and SRM. For the "operation position" sub-factor, the results reveal almost equal importance between the "safety training" and "pre-orientation on job details" attributes. Yilmaz, Burgazoglu, and Man (2022) stated that orientation training increases safety behaviour and has a preventive effect on first workday accidents in the construction industry. The competencies can be enhanced through training and appropriate worker selection.

Surprisingly, the COV factor is the least important factor in enhancing construction safety in Thailand with an importance weight of 0.122. This may be because the pandemic is under control, and construction projects have resumed normal operations. However, the pandemic-related policy and the adequacy of pandemic-related equipment are still crucial to maintaining safety standards. Safety policies, especially ones related to the COVID-19 pandemic, such as mask-wearing, vaccination, and disposal of contaminated wastes, should be practically and effectively implemented in actual practices. Safety rules and regulations should also be regularly updated to tackle COVID-19 and other diseases effectively (Chinda, 2024).

5. Implications to The Thai Construction Industry

The analysis results reveal that HAZ is the most concerning factor in maintaining and improving construction safety in the Thai construction industry. This may be because the companies have to follow the regulations related to hazard identification and risk assessment, such as the Ministry of Industry Announcement No.3 (B.E. 2542) issued by the Factory Act B.E. 2535 on Safety Measures for Operation, the Ministry of Industry Announcement on Safety Measures for Operation (No.4), and the Department of Industrial Works

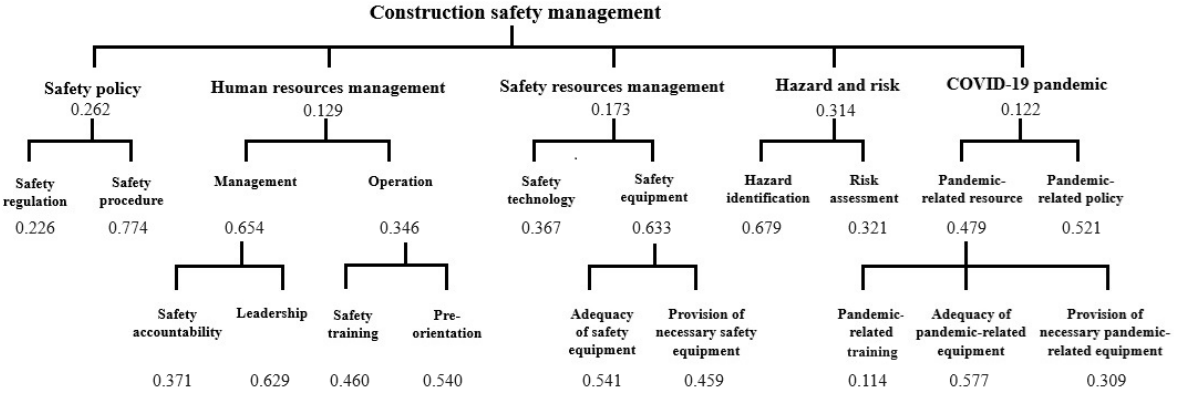

Figure 4. The AHP results

Rule on Criteria for Hazardous Identification, Risk Assessment and Risk Management Plan Compilation B.E. 2543 (Enviliance Asia, 2024). An example of the hazard identification and risk assessment was in a suburban red line project at Bang Sue-Rangsit section using the event tree analysis suggested by the Department of Industrial Works (Sooklamai, & Jiracheewanun, 2020). It demonstrates the significant risk levels to personnel and the benefits of reducing risks for project costs and productivity. To prevent costly events and losses of human life, standard operation procedures by international construction industry best practices should be developed and become documented policy.

Once the hazards and risks are identified and assessed, and the related policies are established to support the safety implementation, the companies should ensure adequate provisions of safety and human resources to implement the safety programs effectively. Many Thai construction companies select safety equipment based on the Thai Industrial Standards Institute and the International Organization for Standardization. The equipment should be easy to use, provide the best comfort for users, and be compatible with other equipment. Standard PPEs in the construction industry include, for example, protective helmets, face and eye protection, earplugs, earmuffs, respiratory protection, guardrails, safety nets, personal fall arrest systems, rubber insulating blankets, rubber insulating gloves, and rubber insulating sleeves (McWashington, 2024).

HRM plays an important role in increasing construction companies' productivity and performance through effective use of the employees. An effective safety program requires adequate and skilled workers. Construction safety training courses may include legal obligations, rights and responsibilities, safety signs, workplace hazards, risk control, PPE usage, confined space safety, and mechanical safety training (SCAL Academy, 2024).

Though the COVID-19 pandemic is over, it is still necessary to include the pandemic-related policy in the companies' goals and provide adequate pandemic-related resources. Chinda (2024) stated that policies like work-from-home and bubble-and-seal may be implemented even after the pandemic to maintain site safety standards. Workers may use work from home when dealing with paperwork, and bubble-and-seal may be applied to ensure safety and health when the sites have contagious diseases.

6. Conclusions

The COVID-19 pandemic has changed the work culture in the construction industry. Many regulations are implemented to mitigate the severity of the pandemic, prevent the occurrences, and ensure the safety and health of workers. To plan for construction safety management effectively, this study examined key factors affecting Thai construction safety after the COVID-19 pandemic. The five key factors are listed in the construction-related literature: POL, HRM, SRM, HAZ, and COV. Interviews were conducted to collect data for the AHP analysis. The interviewees were executives, managers, and supervisors with construction work experience during the COVID-19 pandemic. The analysis results reveal that the HAZ factor is the most crucial factor in enhancing Thai construction safety. It is essential that hazards are identified, and risks are assessed to avoid injuries and accidents. A supportive policy with a clear safety procedure must be established and strictly implemented on sites. The company's goals should also include policies related to the pandemic. The support should cover the adequate provision of necessary safety and pandemic-related equipment and the job orientation and safety-related training provisions.

Though the COVID-19 pandemic is under control, some supportive policies remain to minimize the risks and enhance productivity. For example, a strategy mixing work on location and work from home may be implemented to increase flexibility, reduce safety risks, and lower overhead costs. The budget for pandemic-related resources, such as face masks, alcohol gel, vaccinations, and bins for contaminated materials, should be reserved to avoid the spread of the pandemic and maintain the safety and health of workers.

This study has some limitations. Key factors affecting construction safety after the COVID-19 pandemic are retrieved from the construction-related literature that is not specific to the Thai construction context. The interviewees are from medium- and large-sized construction companies, and have expertise in different construction projects, ranging from the design to road, bridge, installation, and non-residential building projects.

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