Jordan Journal of Civil Engineering, Volume **19**, No. **4**, **2025**
DOI: https://doi.org/10.14525/JJCE.v19i4.04

Jordan Journal of Civil Engineering

Journal homepage: https://jjce.just.edu.jo

Improving Safety Management in Pre-cast Construction Projects

Majda Alhassan [1)*], ***Maher Moustafa*** [2)]

[1)] *Master, Department of Engineering Management and Construction, Faculty of Civil Engineering, Damascus University, Damascus, Syria. * Corresponding Author. E-Mail: majda5.alhassan@damascusuniversity.edu.sy*
[2)] *Professor, Department of Engineering Management and Construction, Faculty of Civil Engineering, Damascus University, Damascus, Syria. E-Mail: mustafa.maher@damascusuniversity.edu.sy*

ARTICLE INFO

Article History:
Received: 24/12/2024
Accepted: 13/6/2025

ABSTRACT

Pre-cast construction projects face significant occupational safety challenges due to high-risk activities, such as lifting, transportation, and assembly, which are often absent in conventional construction. In developing countries, the lack of a comprehensive safety framework exacerbates the problem. Most previous research has focused on traditional construction, leaving a clear gap in addressing the specific safety requirements of pre-cast construction.

This study aims to develop a specialized occupational safety management framework for pre-cast construction sites in Syria. A total of 45 occupational hazards were identified through literature review, expert contributions, and field visits. Data was collected through a questionnaire and analyzed using SPSS.

The results revealed 9 major hazards, such as falling from a height, falling elements, crane failures, poor communication, and the absence of safety protocols. Assembly workers and crane operators were found to be the most exposed, with tower cranes identified as the most hazardous equipment.

The proposed framework consists of two phases: a proactive phase focusing on preventive measures, such as the use of fall protection systems, securing the handling of pre-cast elements, and enforcing strict crane operation protocols; and an implementation phase concerned with incident investigation and corrective actions. This framework provides a practical tool to improve safety performance and serves as a valuable reference for pre-cast construction projects in developing countries.

Keywords: Risk management, Occupational safety, Health, Pre-cast construction, Site, Tower crane, Syria.

INTRODUCTION

The construction sector is considered one of the most hazardous industries in terms of occupational safety, recording significantly higher rates of injuries and fatalities compared to other sectors. Estimates indicated that construction accounts for over 40% of the total work-related injuries worldwide (Al-Maliki et al., 2019), and in 2012, the highest number of fatal work-related accidents was recorded (Fard et al., 2017). Among modern construction methods, pre-cast construction offers notable advantages in terms of speed and quality, but it also introduces additional safety challenges due to its reliance on heavy machinery and complex lifting and assembly processes (Scott, 2019).

Although pre-cast construction is often promoted as a safer alternative to traditional methods (Priya et al., 2018), most existing studies have focused on occupational safety in conventional construction projects, neglecting the unique risks associated with pre-

cast systems. This gap in the literature is particularly evident in developing countries, where safety frameworks remain underdeveloped and fail to address the specific mechanical and logistical hazards of pre-cast construction (Ahmed et al., 2013; Asibey et al., 2021).

This study addresses a clear research gap: the absence of a specialized framework for managing occupational safety in pre-cast construction projects, particularly in resource-limited environments, such as Syria. In response, this research contributes by developing a two-phase safety management framework tailored to the specific risks of pre-cast construction in Syria, integrating preventive and corrective strategies adapted to local constraints and working conditions.

PREVIOUS STUDIES

The field of occupational safety in pre-cast construction projects has received limited academic attention to date. While several studies have addressed safety in traditional construction contexts, there is a clear deficiency in developing specialized frameworks that tackle the unique risks associated with pre-cast construction. Most existing research focuses on general methodologies that do not reflect the specific working conditions in developing countries or resource-constrained environments.

For example, Shaari et al. (2016) concentrated on the installation phase of pre-cast concrete elements in Malaysia, monitoring accidents related to this phase and offering general recommendations, yet they did not develop a comprehensive risk management framework. In the United States, Fard et al. (2017) examined accident types on both manufacturing and construction sites, finding that falls from a height and collisions accounted for the majority of accidents. However, their study primarily aimed at preventive planning rather than at building a fully integrated safety framework.

Chopade et al. (2021) identified key causes of accidents in India and discussed the potential of emerging technologies such as virtual reality and sensors, though their applicability in low-resource settings remains unclear. Similarly, (Ahmed et al.,2013) developed a general safety framework in Pakistan, but did not adequately address risk identification and evaluation tailored for pre-cast construction. Furthermore, (Othman et al., 2018) focused mainly on contractors' perspectives, neglecting other stakeholders who play a vital role in comprehensive safety strategies.

Additionally**,** Ketabi et al. (2022) proposed a strategic planning framework at the feasibility level to optimize safety-related cost planning, but did not specifically address the unique challenges of pre-cast construction. Chen et al. (2022) applied advanced ontology technology within a BIM environment to manage safety risks in pre-fabricated building projects, an important innovation; however, its practical applicability in countries with limited technical infrastructure is uncertain.

Therefore, despite the valuable contributions of prior studies, there remains a significant gap in the literature regarding the development of specialized, realistic, and applicable safety management frameworks for pre-cast construction projects in developing countries, such as Syria. This study aims to fill this gap by developing an occupational safety framework that addresses the distinct risks, working conditions, and resource constraints characteristic of this specific environment.

RESEARCH PROBLEM

Pre-cast construction projects involve specific risks that impact the occupational safety of work crews, due to activities, such as lifting, transporting, and installing heavy elements. Despite these challenges, there is a lack of clear frameworks and effective methodologies to enhance safety in such projects, while most previous studies have focused on traditional construction. This highlights the need to develop a tailored approach to improve safety in pre-cast construction.

MATERIALS AND METHODS

Theoretical Study

The Concept of Pre-cast Construction: is a process that involves planning, designing, manufacturing, and assembling building elements in a place other than the actual place of implementation, to accelerate and support the efficiency of the construction process at the final site, according to the National Institute of Building Sciences (Elhsain, 2014).

At present, there are three international systems in how to pre-build, classified depending on how the weights are carried, transported, and distributed as follows (Al-Bayati et al., 2011): (Bearing Walls)-

(Systems Frame)- (Systems Box).

The Concept of Occupational Safety and Health: It is a field that aims to protect various categories of workers from immediate and/or long-term hazardous health impacts that may result from risks associated with work, its environment, or conditions by addressing the environmental, technical and personal factors leading to these risks and improving the work environment and conditions, in a way that ensures that workers enjoy appropriate physical, mental and social health (Zhou et al., 2022).

Qualitative Risk Analysis: It examines the risks and arranges them according to their priority, based on the probability of the occurrence of those risks (P) and their impact (I) on the project, where the risk is measured as the probability of a specific unwanted event and its undesirable consequences, the level/degree of risk is calculated through Equation (1) (Khayat, 2011; Saleh, 2020):

Risk level R= Probability (P) × Impact (I) ……. (1)

The Statistical Study

A total of forty-five (45) occupational safety hazards associated with pre-cast construction sites were identified and analyzed based on a multi-source methodology to ensure comprehensive and accurate results. This included a review of scientific studies and published research addressing hazards in pre-cast construction, such as the studies by (Shaari et al., 2016), (Chopade et al., 2021), (Fard et al., 2017), (Mohandes et al., 2022), and (Li et al., 2014), which helped build an initial knowledge base of the most common and recurring potential hazards.

Additionally, several sessions were held with a group of experts and professionals involved in pre-cast construction projects to discuss and evaluate potential hazards based on their practical experience. This allowed for the inclusion of hazards specific to the local context. Furthermore, field visits were conducted to pre-cast construction sites in Damascus and its countryside to observe real working conditions and identify the most critical operational hazards facing on-site teams.

After gathering and analyzing the data, the identified hazards were classified into six main categories (see Table 1) based on their nature and impact on occupational safety. The study also identified the equipment and machinery most commonly associated with these hazards, as well as the work teams most exposed to them.

The Questionnaire Design

The questionnaire form consists of four sections as follows:

Section I: Contains general information specific to the respondents.

Section II: Consists of a table of risks (classified into six groups) that affect occupational safety.

Section III: Identification of equipment and machinery causing risks affecting occupational safety at the work site.

Section IV: Identification of work crews most affected by occupational safety risks at the site.

- The Likert pentameter was used, which ranges between 1 and 5.

- The target sample member to answer the questionnaire are project managers, site engineers, supervisory engineers, contractors, and technicians (assistant engineers and technical observers) who are most familiar with work accidents that affect workers during the implementation of pre-cast construction projects. Equation (2) was used to determine the sample size representing the studied population.

$$n = \frac{z^2 * \sigma^2}{E^2} \quad \ldots\ldots \quad (2)$$

It was found that the sufficient sample size should be greater than or equal to (46) at a confidence level of (90%), (62) questionnaire forms were distributed within Damascus governorate and its countryside, (57) forms were retrieved and two forms were excluded for not completing the answers, and (55) forms were approved for the study.

It is worth noting that the sample size was relatively limited, due to field challenges associated with the security and economic conditions imposed by the war in Syria, which restricted access to a larger number of project sites and participants from diverse categories. The geographical scope of the study was also limited to Damascus and its surrounding countryside, which may constrain the generalizability of the findings to other regions with different operational and regulatory conditions in the pre-cast construction sector at the national level. Nevertheless, this limitation was mitigated by diversifying the data collection methods,

including literature reviews, expert interviews, and field visits, which helped enhance the credibility and comprehensiveness of the findings within the studied local context.

Table1. Risks and classifications of occupational health and safety in pre-cast construction projects

Risk	Classification	Risk	Classification
1. Lack of practical experience/skill of workers	**1. Workers' risks**	24. Failure to inspect and approve equipment or machinery	**2- Risks of the nature of the project/work site**
2. Lack of practical experience/skill of workers on site		25. Tower crane overload	
3. The physiological state of workers		26. Forklift overturning	
4. Workers' negligence/workers' fault		27. Connecting the tower crane to the facility	
5. Inappropriate use of PPE		28. Failure to take into account the ability of the boom to cover the site	
6. Work in an unfriendly environment		29. Crane rust for a long passage	
7. Poor communication when operating the crane (lifting/downloading/installing) pre-cast components	**2. Risks of the nature of the project/work site**	30. Adverse weather conditions (rain - wind - high temperatures - fog ... etc.)	**4. Environmental Risks**
8. Falling from a height		31. Insects and animals	
9. Use of large/heavy pre-cast elements		32. Earthquakes	
10. Excessive storage/stacking of pre-cast components		33. Topography of the region	
11. Crash of pre-cast components from a height		34. Lack of a safety plan	**5. Safety management risks**
12. Electric shock		35. Lack of safety education and training	
13. Quality defects of pre-cast components		36. Incomplete safety codes and standards	
14. Poor management of on-site traffic planning		37. Lack of non-safety supervision at the site	
15. Incorrect installation and installation of components		38. Lack of instructions/safety measures	
16. Poor permanent connections used		39. Unavailability of tools (PPE)	
17. Poor welding of joints		40. Lack of ambulance on site	
18. Lack or damaged/non-maintenance of equipment	**3. Equipment/ machinery hazards**	41. Lack of registration and Inspection department	
19. Not using temporary props		42. Bad organizational climate	**6. Risks of different procedures**
20. Drop load lift		43. Poor resource management	
21. Collision with an object or equipment/vehicle		44. Not solving problems	
22. High-tower cranes		45. Unsafe design	
23. Dismantling of rings and wires when lifting material or installation/crane cable breakage			

The Data Analysis and Processing

Using SPSS and Excel to process data, the test was performed on the studied sample, where the internal stability coefficient (Cronbach's alpha) was 0.976, which is greater than 0.7. It indicates high reliability in the responses of the sample members to the questionnaire. The external stability of the questionnaire was calculated by the Spearman correlation coefficient and its largest value was 0.85 (greater than 0.75), which indicates the strong direct correlation between the studied factors and the high stability of the questionnaire.

- **Section I of the Questionnaire: General Information about Participants**

1- Field of work: The total percentage of (supervision engineers-site engineers - project managers) reached

65%, which helps benefit from their experience, as they are in direct contact with work on the site.

2- Qualification: More than 95% of the respondents have higher degrees, increasing the answers' accuracy.
3- Years of practical experience in the field of pre-cast construction: Approximately 60% of those surveyed have more than ten years of experience, which increases the reliability of the answers.
4- Type of sector: The percentage of the public sector reached 54%, that of the private sector 35%, and that of the joint sector 11%.

- **Section II of the Questionnaire: Risk Analysis**

The analysis of risks affecting occupational safety during the construction of pre-cast projects was based on the following:

- The probability of occurrence of hazards;
- The degree of impact of hazards on occupational safety;
- The Relativity Importance Index (RII). (Rashid, 2015; Hamada et al., 2021).

In this study, the RII can be calculated for each risk for all groups included in the questionnaire form using Equation (3) and its values range from [0,1] (Chopade et al., 2021).

$$RII=QI*SI \quad (3)$$

OI: Occurrence Index, and SI: Severity Index are calculated from Equation (4), and the values are between [0,1].

$$OI = \Sigma W / (A * N) \quad (4)$$

Occupational safety hazards in pre-cast construction projects were ranked and classified based on the Relative Importance Index (RII). The results were presented graphically and arranged in descending order, as shown in Figure (1). The significance levels were determined using the probability-impact matrix, based on the thresholds proposed by Alghonamy (2015), as follows: Very High: ($RII \geq 0.8$), High: ($0.6 \leq RII < 0.8$). Medium: ($0.4 \leq RII < 0.6$). Low: ($0.2 \leq RII < 0.4$). Very Low: ($RII < 0.2$).

Accordingly, the risks were classified by their severity level, as presented in Table 2. It is noteworthy that none of the identified risks reached the threshold for a "Very High" importance level based on the adopted RII criteria. However, several risks were classified as having "High" importance, such as: falling from a height, falling of pre-cast concrete elements, and collisions with equipment.

Although these risks did not mathematically fall under the "Very High" category, they are considered critically important from a practical safety management perspective and thus require effective preventive measures and prioritization in safety planning. The significance levels of the probability and impact matrix (Alghonamy, 2015) were adopted, and the risks were arranged according to the significance level mark (severity), as shown in Table 2.

Table 2. Ranking of risks according to significance level markers

Risk	Level of importance
There isn't any risk	Very high
Falling from a height (1)	High
Crash of pre-cast components from a height (2)	
Collision with object or equipment (non-vehicle)/vehicle (3)	
Failure to inspect and approve equipment or machinery (4)	
Dismantling of rings, hooks when lifting materials and installation (5)	
Workers' negligence/workers' fault (6)	
Poor communication when operating the crane for (lifting/downloading/installing) pre-cast components (7)	
Misuse or unavailability of personal protective equipment (PPE) (8)	
Absence (safety instructions / safety protection measures) (9)	
32 Risks	Medium
Non-problem solving (43)	Low
Physiological status of workers (44)	
Insects & animals (45)	

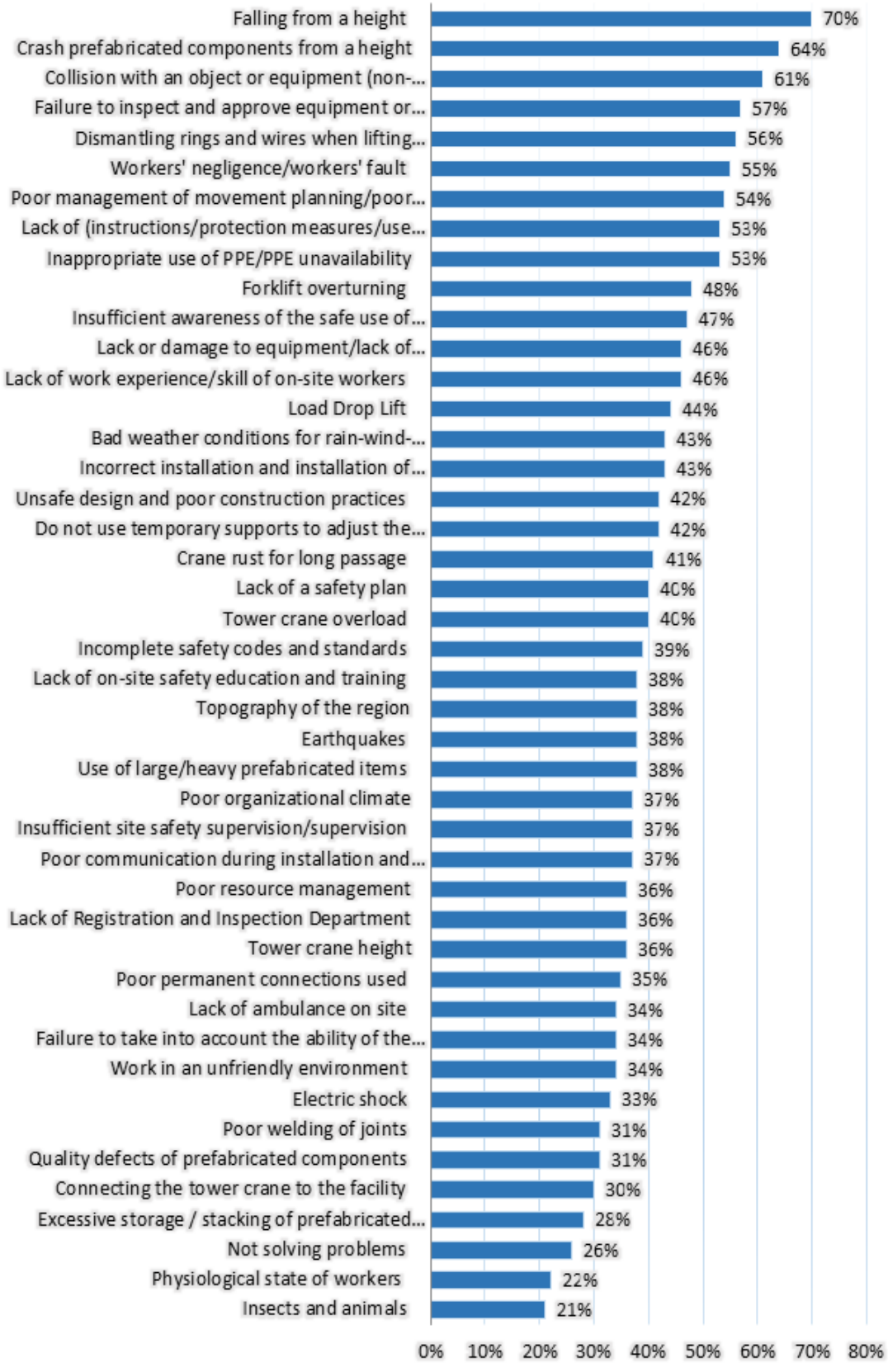

Figure (1): Ranking of risks according to the significance index

- **Sections III and IV of the Questionnaires: Identification of equipment and machinery causing safety hazards and work crews most affected by safety hazards at the work site**

A five-point Likert scale was utilized to assess both the likelihood of equipment and machinery contributing to occupational safety risks and the extent to which various work crews are affected by on-site hazards. The Relative Importance Index (RII) was calculated based on Equation (5) while the standard deviation was obtained using SPSS program. The interpretation of importance levels followed the classification proposed by Algahtany (2021).

$$\text{Importance Index (II)} = \frac{5*\sum N_5 + 4*\sum N_4 + 3*\sum N_3 + 2*\sum N_2 + 1*\sum N_1}{5*N} \quad (5)$$

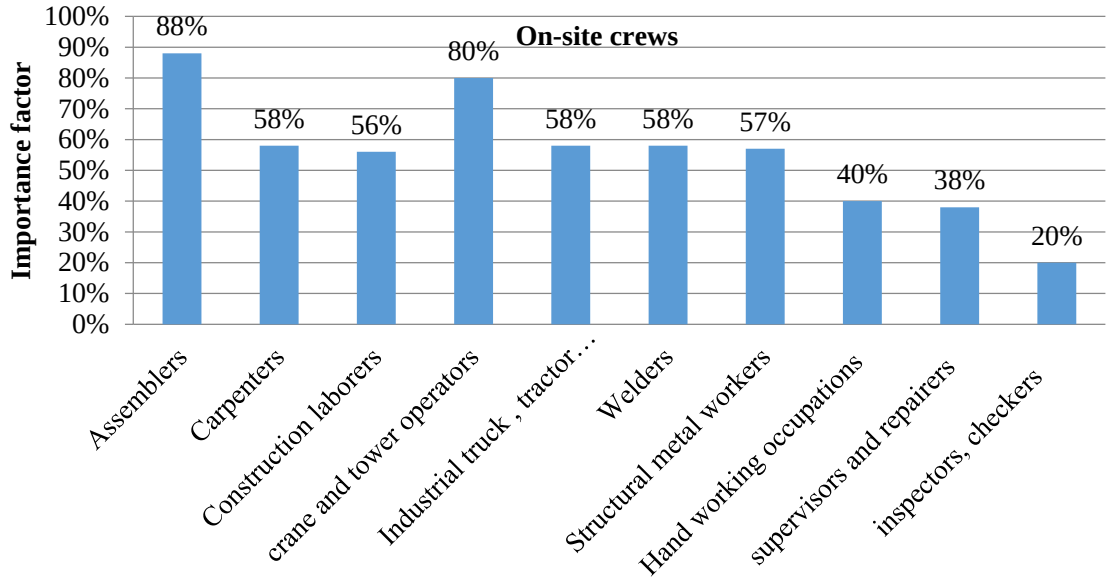

Figure (2): Ranking of work crews according to importance

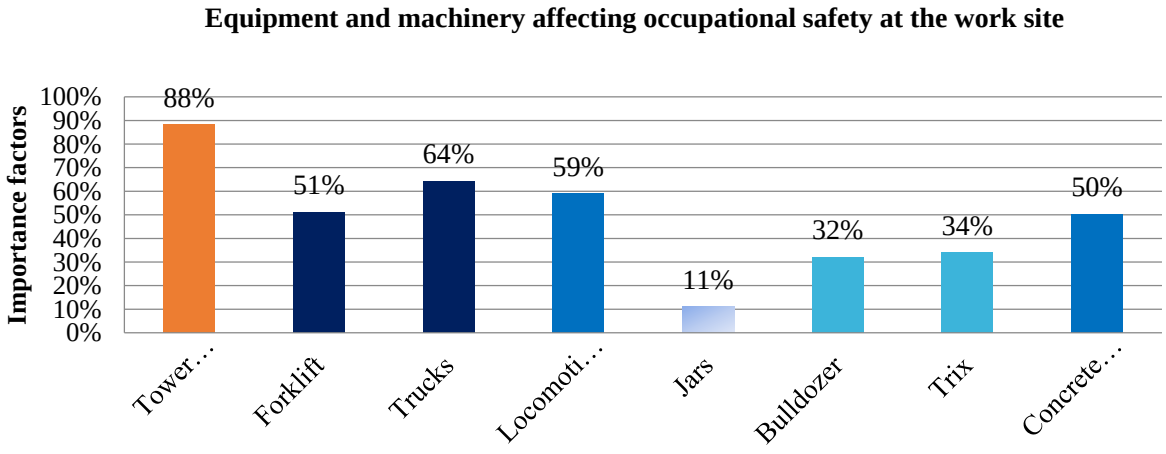

Figure (3): Equipment and machinery ranking according to importance

The results indicated that assemblers and crane operators are the most exposed to hazards on construction sites, followed by general construction workers. The tower crane, followed by the locomotive and trailer, were identified as the most hazardous equipment. These findings point to the high risks

associated with lifting and handling operations, consistent with previous studies on pre-cast construction projects.

They underscore the importance of directing preventive measures toward the most vulnerable groups through specialized training, performance monitoring, and the provision of PPE—contributing to reduced injuries and improved safety and efficiency on-site.

Development of a Framework for Improving Occupational Safety in Pre-cast Construction projects

A framework was proposed to enhance occupational safety at pre-cast construction sites in Syria. The framework consists of two main phases: the first involves proactive measures taken prior to project execution, while the second is applied during project implementation. The proposed framework was reviewed and evaluated by a panel of experts in occupational safety and pre-cast construction.

Phase I of the Framework: Proactive Measures

Before the commencement of any pre-cast construction project, it is essential to develop a comprehensive safety plan and incorporate it into the official project documentation. This phase comprises five key components:

i. Regulations, Policies, and Safety Legislation

Effective occupational safety management begins with the establishment of clear, written regulations and policies that define responsibilities across all organizational levels. These policies must align with Syrian regulations, particularly Decree no. 450 and its general technical specifications for the execution of buildings and infrastructure (Issa, 2016). Strict enforcement, consistent monitoring, and accountability are necessary to ensure compliance.

ii. Organizational Structure of Safety and Responsibilities in the Project

Integrating a dedicated safety unit within the contractor's organizational structure is essential to ensure the effective implementation and supervision of safety protocols. This unit should be staffed by qualified personnel with specialized training in occupational safety. The allocation of safety responsibilities should be proportionate to the project's scale: in small-scale projects, the owner or project manager may directly oversee safety measures, while in larger projects, these responsibilities must be delegated to safety managers and supervisory staff (Chopade et al., 2021).

iii. Training and Awareness of Project Workers

Training and raising awareness among workers are fundamental to fostering a strong safety culture. Training sessions should cover the identification of site hazards, proper use of equipment and personal protective equipment (PPE), first aid procedures, and regular dissemination of safety updates. Warning and instructional signage should also be prominently displayed on-site (Ahmed et al., 2013).

iv. The Most Common Hazards, Equipment/ Machinery Most Impacting Safety and Crews Most Affected by the Risks

Based on the results of the statistical analysis and the Relative Importance Index (RII), nine major risks were identified. The most critical ones include: falls from a height, falling elements, crane failures, poor communication, the absence of safety protocols, and improper use of protective equipment. Assemblers and crane operators were found to be the most at-risk workers, while the tower crane was identified as the most hazardous equipment. These findings emphasize the need for targeted preventive measures in these critical areas (Chopade et al., 2021). The framework recommends conducting detailed risk assessments in work areas before construction begins.

v. Preventive Safety Measures

In light of the identified hazards, the framework recommends implementing a set of preventive measures aimed at avoiding accidents or minimizing their impact. These include the use of fall protection systems, and safe handling of pre-cast elements. Strict protocols should govern crane operations, including regular inspection of cables, hooks, and lifting accessories, as well as clear communication among crew members during hoisting tasks, improvements in working conditions, routine risk assessments, and the development of emergency response plans (Fard et al., 2015); (ILO, 2017), (Chopade et al., 2021).

Phase II of the Framework: Implementation of the Project Taking into Account the Safety Plan

This phase involves the active implementation of the

safety plan during project execution and includes the following components:

i. Safety Inspection Procedures

Regular and systematic inspections are carried out by a specialized team, focusing on high-risk areas and activities as indicated by the survey results. Observations are documented in incident reports, which serve as critical tools for identifying actual and potential risks. Immediate action is taken to address hazards that require urgent intervention, thereby reducing violations and accidents (El-Mashaleh et al., 2010).

ii. Accident Investigation

Investigating accidents plays a fundamental role in identifying root causes, thereby preventing recurrence through enhanced supervision, modified work procedures, targeted training, and effective corrective actions. Moreover, it facilitates timely communication of specific hazards to workers, increasing awareness and preparedness on site (Chopade et al., 2021).

iii. Description of Accidents that Occurred in The Project

Accidents vary depending on the nature of the work and the equipment involved. Each incident should be analyzed in terms of its causes, consequences, and the affected personnel. Necessary adjustments are made throughout the execution phase, and the safety plan is updated accordingly. A final quantitative assessment is conducted based on the numbers and types of actual incidents, serving as a performance measure for the adopted safety system.

iv. Risk Level Assessment

Risk levels are assessed based on two criteria: likelihood of occurrence and severity of impact. Accident frequency and severity indices are calculated using the number of injuries, lost workdays, and total hours worked, in accordance with international standards (Ali, 2007); (ILO, 2017). This assessment helps in identifying critical risk points that require urgent intervention or systematic improvement.

v. Corrective Actions

A corrective action plan is developed to address deficiencies identified through inspections and investigations. This plan includes identifying deviations or changes that contributed to the incidents and updating the safety plan accordingly. Each adjustment is followed by a reassessment to determine:

- The adequacy of the initial safety assessment and preventive measures.
- Any previously undetected vulnerabilities.
- The corrective steps necessary to improve current and future safety performance (Ahmed et al., 2013).

At the project's conclusion, a final quantitative risk evaluation is performed, and a safety database is established to inform future planning efforts. This provides a foundation for more adaptive and responsive systems in upcoming projects.

Checking the Proposed Frameworks

The proposed framework was presented to several experts in this field, to view, verify, and express their opinions about it with any suggestions or observations (adding, modifying, deleting) to be improved to reach the optimal shape of the frame by filling in the required points. A Likert five-point scale was used, as shown in Table 3.

Table 3. Evaluation of the proposed framework

Average expert assessment	Not good	middle	neutral	Good	Very good	The idea put forward
4.75				**	******	The suitability of the proposed framework for the reality of pre-cast construction in Syria
3.5		*	**	*****		Frame clarity and understanding
3.63			***	*****		Applicability
3.625		*	*	******		Providing a database to benefit from and refer to in future projects
4		*		*****	**	Contribution to the completion of the project with the required quality
4.25			*	****	***	Contribution to the completion of the project in the required time and cost
4.25				******	**	Contribution to the improvement of occupational safety practices on site

3.75		*	*	*****	*	Assisting safety officials in detecting hazards early
4		*		*****	**	Helping develop safe ways of operating and create a safer working environment
4.5				****	****	Increasing workers' awareness of occupational safety matters and understand and recognize risks
3.88			**	*****	*	Improving resource management (materials-workers-mechanisms)
4.01						Overall expert evaluation of the ideas put forward

The experts' assessment of the framework was good and their observations and suggestions were taken into account to help develop the framework in its final form (Figure (4)).

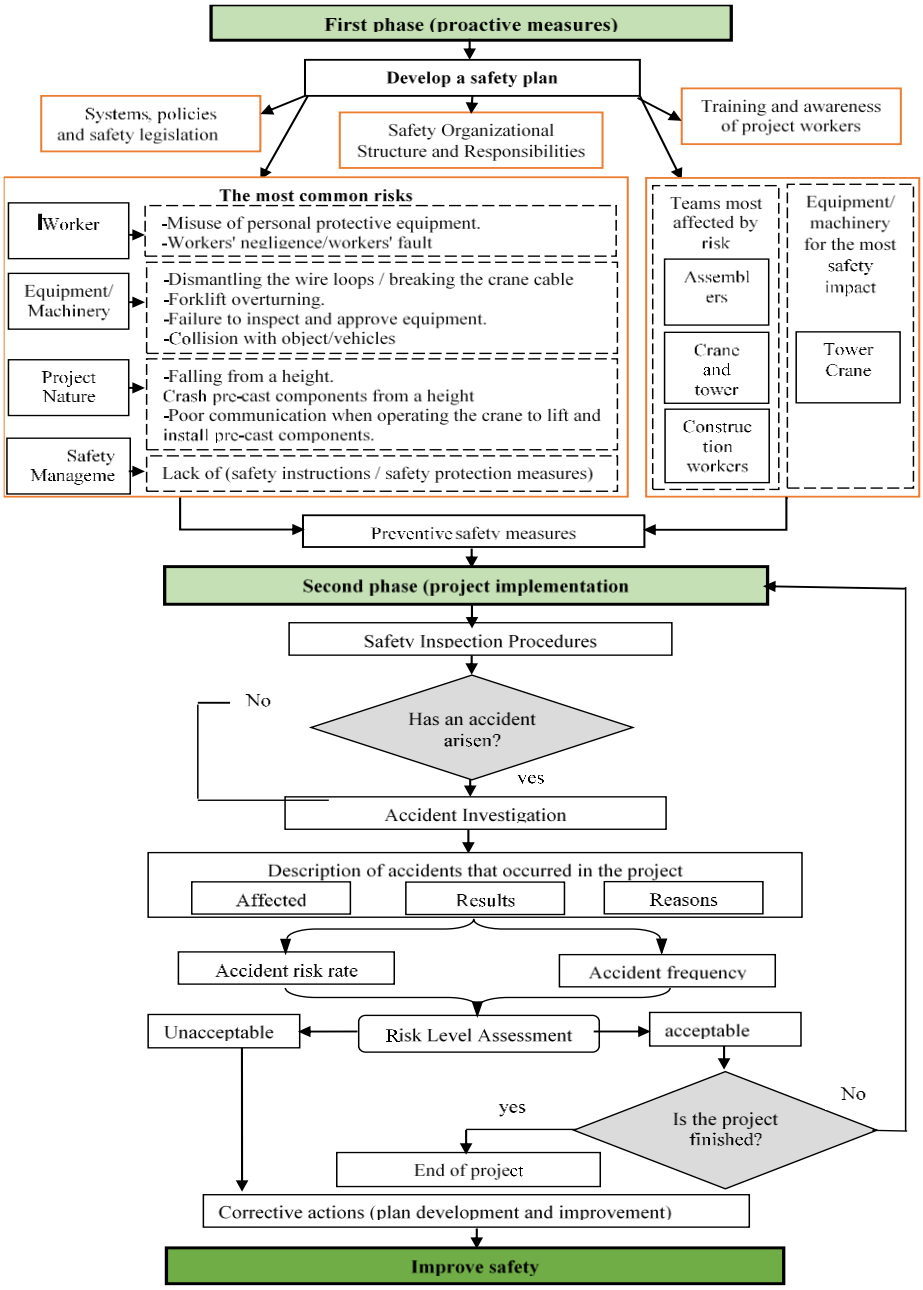

Figure (4): Developing a framework to improve safety within pre-cast construction projects

Practical Implementation of the framework

Although the proposed framework is clearly structured, its implementation faces challenges, such as the lack of hands-on training for workers and supervisors (Chi et al., 2020), limited resources, and the absence of legislative support (Zhou et al., 2022). These challenges are particularly evident in developing countries, like Syria, where training programs are weak, financial capabilities are limited, and specific regulations for pre-cast construction are lacking. To overcome these obstacles, it is recommended to develop short and flexible training programs focused on the most critical risks identified in pre-cast construction projects, and to establish partnerships with local unions and institutions to pilot the framework in the field before scaling it up. Continuous improvement should be ensured by gathering feedback from workers and supervisors and adjusting safety measures based on field observations, thereby enhancing the framework's chances of success and effective integration into the construction sector.

RESULTS AND DISCUSSION

a. This study identified nine high-risk hazards that significantly impact occupational safety in pre-cast construction projects. These include: falling from a height, worker negligence or lack of experience, breakage of pre-cast components during lifting, detachment of rings, hooks, or wires, crane cable rupture, poor communication during lifting and installation, absence of safety instructions or protection measures, misuse or unavailability of personal protective equipment (PPE), and failure to inspect and approve equipment.
b. Among all worker categories, assembly workers and crane operators were found to be the most exposed to serious risks due to the nature of their work, which involves handling heavy components and working beneath suspended loads. This highlights the need for meticulous planning, strict adherence to PPE use, and the application of effective practices to prevent falls during installation.
c. The tower crane was identified as the most dangerous piece of equipment on site, necessitating strict safety protocols and intensive operator training.
d. The proposed framework offers several contributions:

- ✓ It provides a database of past accidents that can be referred to during safety planning and evaluation.
- ✓ It assists implementation companies in updating their safety policies in pre-cast construction projects.
- ✓ It is specifically designed for the nature of pre-cast construction, which differs from conventional frameworks due to faster execution and the complexity of coordination between production, transportation, and on-site assembly. It emphasizes a proactive phase that focuses on risk anticipation rather than merely reacting after incidents occur. It was developed based on the Relative Importance Index (RII) analysis of actual field-identified hazards in the Syrian context, making it more relevant to local realities. It involved local experts in the framework evaluation process, which enhances its practical applicability and credibility.

The findings of this study are consistent with previous literature, confirming that assembly workers and crane operators are most exposed to risks, particularly during stages that require precise coordination among teams—such as those highlighted in the study by Zhou et al. (2022). Similarly, Hasanzadeh et al. (2019) pointed out that the absence of proactive safety measures and insufficient planning directly contribute to accident occurrences.

In the Syrian context, unique challenges, such as a weak regulatory infrastructure and the lack of binding laws for pre-cast projects, make these risks even more acute. Therefore, the proposed framework not only aligns with global trends, but also responds to urgent local needs, aiming to address the legislative and regulatory gaps in the Syrian construction market.

Suggestions for Future Studies

- How can virtual reality, sensor technologies, and artificial intelligence improve occupational safety management and early warning systems in pre-cast construction projects?
- To what extent are specialized training programs effective in increasing workers' hazard awareness and enhancing adherence to safety procedures in pre-cast construction environments?
- What legal, regulatory, and cultural factors influence the development, implementation, and enforcement of occupational safety standards in the pre-cast construction sector within conflict-affected areas?

- How can an integrated occupational safety management model be designed to fit local conditions and contribute to reducing accidents in pre-cast construction projects?.

REFERENCES

Ahmed, W., and Abid, M. (2013). "Development of a framework for implementing safety on construction sites. International Journal of Advance Research (IJOAR), 1 (3).

Albiati, H., and Sirhan, M. (2011). "Study of the performance efficiency of pre-cast construction: Applied research on the building of the Department of Civil Engineering - University of Takrit". Diyala Journal of Engineering Sciences, 4 (2), 1-22.

Algahtany, M. (2021). "Factors affecting cost overruns in construction projects". Proceedings of International Structural Engineering and Construction, 8 (1), CPM-14.

Alghonamy, A. (2015). "Cost overrun in construction projects in Saudi Arabia: Contractors' perspective". International Journal of Engineering and Technology (IJET-IJENS), 15 (4), 35-42.

Ali, M.M. (2017). "Health and safety and their impacts on production efficiency in industrial enterprise: A case study: Henkel - Algeria, Chalghoum Eid Complex". Master's Thesis, Mentouri University of Constantine.

Al-Maliki, T., and Ammar, A.R. (2019). "Factors affecting the safety of workers in construction projects in the Kingdom of Saudi Arabia". Emirates Journal for Engineering Research, 24 (2-3).

Asibey, D., Ayarkwa, J., Acheampong, A., Adinyira, E., and Amoah, P. (2021). "Framework for improving construction health and safety on Ghanaian construction sites". Journal of Building Construction and Planning Research, 9, 115-137.

Chen, Y., Zhang, X., and Li, B. (2022). "Evaluation and improvement of construction safety for pre-cast buildings under the resilience concept". Materials, 14 (11), 3459.

Chi, S., Han, S., and Kim, D.Y. (2020). "Exploring barriers to safety training implementation in construction". Journal of Safety Research, 72, 203-210.

Chopade, R., Pathak, P., Chougule, R., Bothra, N., Mane, N., and Minde, P. (2021). "Analysis of safety management in pre-cast construction projects". Turkish Journal of Computer and Mathematics Education, 12 (6), 5225-5236.

Elhsain, E. (2014). "The decision to use off-site manufacturing (OSM) systems for house building projects in the UK". Engineering, Environmental Science, Business, 2(1).

El-Mashaleh, S.M., Al-Samadi, M.B., Hayari, H.K., and Rababeh, M.S. (2010). "Safety management in the Jordan construction industry". Jordan Journal of Civil Engineering, 4 (1), 47-54.

Fard, M.M., Terouhid, S.A., Kibert, C.J., and Hakim, H. (2017). "Safety concerns related to modular/pre-cast building construction". International Journal of Injury Control and Safety Promotion, 24 (1), 10-23.

Hamada, M., Nayfeh, M., and Amoudi, O. (2012). "Construction risk management for construction projects in Syria". Damascus University Journal of Engineering Sciences, 28 (1), 129-150.

Hasanzadeh, S., Esmaeili, B., and Dodd, M.D. (2019). "Measuring safety performance using leading indicators: A case study in construction". Safety Science, 115, 285-296.

International Labour Organization. (2017). "Technical guide for training occupational safety and health inspectors". ILO, Cairo, Egypt.

Issa, S. (2016). "Safety management in road and bridge projects in Syria during implementation". Master's Thesis, Damascus University, Faculty of Civil Engineering.

Ketabi, A.B., and Heravi, G. (2022). "Developing a framework for evaluating construction project safety levels and optimal cost allocation to safety influential factors". Engineering, Construction and Architectural Management, (2), 643-668.

Khayat, W.G. (2011). "Study of the risks of projects of the Public Corporation for Potable Water and Sanitation in Aleppo". Master's Thesis, University of Aleppo, Faculty of Civil Engineering.

Mahmoud, A.R. (2022). "Developing a framework for assessing safety risks in construction projects during the implementation phase". Master's Thesis, Damascus University, Faculty of Civil Engineering.

Mohandes, R.S., Hem, S., and Yoo, J.S. (2022). "Occupational health and safety in modular integrated construction projects: The case of crane operations". Journal of Cleaner Production, 342, 130978.

Othman, I.M.H., Napiah, M., Hashim, Z., and Cai, Z. (2018). "The framework for effective safety control and implementation at construction project". International Journal of Engineering Technologies and Management Research, 5 (12), 28-42.

Priya, P.K., and Neamitha, M. (2018). "A comparative study on pre-cast construction, unconventional construction, and traditional construction". International Research Journal of Engineering and Technology, 5 (8), 839-840.

Rashid, E. (2015). "Assessing the impact of risks on the objectives and safety of construction projects in Iraq". Journal of Engineering, 21 (4).

Saleh, H.A. (2020). "An integrated disaster risk management plan of cultural heritage: A case study in the Syrian coastal region". Arabian Journal of Scientific Research, 2020 (1), 1-16.

Scott, J.J. (2020). "Improving construction safety with prefabrication and modular construction technology". Journal of Building Engineering, 27, 100979.

Shaari, A.A., Zaki, M.M., and Muhamad, W.Z. (2016). "Safety of Pre-cast concrete installation for industrialized building system construction". International Journal of Applied Engineering Research, 11 (13), 7929-7932.

Zhou, Z., Irizarry, J., and Li, Q. (2022). "Safety challenges in pre-fabricated construction projects: A global review". Journal of Construction Engineering and Management.