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Integrating Lean Design Tools and Safety Practices to Enhance Safety Performance in Indian Construction

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Abstract: Improving safety among construction companies is very competitive. The construction sector in India is characterized as one of the hazardous sectors with the highest incidents and injury rates. Accident in the construction workplace leads to human illness and loss of business productivity. In literature, it was documented that well-studied pre-task planning can eliminate or prevent many accidents/incidents on the construction site. Previous research pointed to the execution of safety practices and lean tools to remedy the causes of incidents/injuries in different construction workplaces worldwide. However, studies on implementing lean design tools and safety practices are marginal in the Indian construction scenario. This study aims to design a way to reduce accidents in the Indian construction workplace using lean design tools and best safety practices. This study explores the connection between construction safety practices and lean design tools and their impacts on construction safety. The findings of this study will have implications for practitioners and contractors in the Indian construction sector to improve safety performance.

Keywords: Lean tools, Construction Industry, Occupational accidents, Safety

1. Introduction

The construction industry has shown poor safety performance, judging from the number of relevant articles, considerable research conducted, and books published. For instance, in regions like the United Kingdom (HSE, 2019), Hong Kong (Wong et al., 2016), and Kenya (Kemei et al., 2015), construction accounts for a large number of accidents than any other industry. In the same line, Chellappa et al. (2021) stated that accidents in the Indian construction sector can have many accidents/injuries due to the involvement of many stakeholders and the project's dynamic nature. Besides consequences on human illness, accidents also direct in losses of productivity and extra indirect cost gained through litigation costs, medical treatment, and insurance costs (Vigneshkumar and Salve, 2020). In general, construction accidents that occur in the workplace represent severe safety problems that have to be still addressed (Hoyle, 2009).

Workers working in the industry are demotivated to this extent, posing a huge risk to the economy and sustainability. Therefore, construction safety has always been a significant challenge to the contracting organizations' stakeholders, practitioners, and owners. Different initiatives were launched by the Indian government (Vigneshkumar et al., 2019) to enhance the safety performance of construction companies. While many studies (Vigneshkumar et al., 2018; Vigneshkumar and Salve, 2018; Chellappa and Muthu, 2021; Vigneshkumar and Salve, 2022) have been conducted recently to enhance the safety performance of the construction sector from different perspectives in India, they did not offer a straightforward approach to preventing accidents. Hence, a viable and understandable approach to preventing accidents is still lacking. Furthermore, the possible effect of safety practices like workers' participation in decision making, involvement of workers in task scheduling, production planning, and place of work organization in decreasing accidents in the Indian construction workplace have not been considered.

Hinze (2002) stated that in many countries, the construction industry started adopting best safety practices in different ways to prevent accidents/injuries. The construction industry institute (CII) states the best safety practices as an approach that, when implemented successfully, could improve companies' performance (Meltz, 2009). Safety practice is vital in the lean concept to attain consistent workflow in construction processes (Chellappa et al., 2021). Subsequently, incidents are seen as key causes of time waste, money, materials, and labor that are barriers to consistent workflow and value delivery. Lean construction avoids waste throughout the life-cycle of construction using lean construction principles (Fewings, 2013). It is a continuous process of minimizing materials waste, time, and labor to make the highest potential quantity of worth for the consumer (Song et al., 2008). Fewings (2013) pointed out that lean construction tools can help enhance safety performance in construction workplaces. Workers' issues of poor safety performance can be improved by participation in the construction industry (Gambatese and Pestana, 2014).

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Several studies (e.g., Fewings, 2013) recommended executing the best safety practices and lean design tools as a remedy for causes of accidents in different construction workplaces worldwide. However, studies on implementing lean tools and safety practices have still not been addressed from the Indian construction perspective. Therefore, this study proposed reducing accidents in Indian construction using lean construction tools and safety practices.

2. Lean design tools and safety practices in construction

Construction, demolition, and renovation include repetitive tasks with different equipment, machines, and techniques where workers are exposed to various hazardous conditions (Hughes and Ferret, 2008), which tends to increase the chances of accidents/injuries at the workplace (Basher, 2011). Changes in working environments, frequent changes in location, materials variation, nature of work, weather effects, continuous movement, and weather effects are other factors associated with the workplace (Perttula et al., 2003) which result in accidents.

Table 1. Best Safety Practices (created from Hinze (2002)).

Best safety practices	Description
Demonstrated management commitment	Management's commitment should be sincere and communicated to the workers' level. Senior-level and top management should review safety reports and investigate recordable accidents and injuries.
Staffing for safety	Safety personnel must be appropriately allocated and should ensure that the safety needs are being satisfied in projects, training is carried out properly, and safety supports are correctly provided daily to the field personnel.
Safety planning: pre-project and pre-task	Pre-project planning ensures that safety analysis is conducted before starting the project, and pre-task planning ensures that safety plans are integrated into daily routine work plans.
Safety training and education	Must start with the job site training and orientation of every worker. Education must focus on the needs of individuals, whether they are supervisors, field workers, or managers. It is required to provide extra education to workers if worksite conditions change.
Worker's involvement	Workers are actively involved in the safety practices implementation. Such involvement can be achieved through worker participation on safety committees, input through worker safety perception surveys, and observations of worker behavior.
Evaluative and recognition/reward	Workers must be rewarded whose commitments enhance safety performance in the workplace.
Subcontract management	If the safety program is more effective, the subcontractor must be involved in drug testing, safety planning, orientation training, etc.
Accident/incident investigation	This is conducted to identify the root causes of accidents and near misses in the workplace and results shared with workers.
Drug and alcohol testing	This includes workers testing for substance abuse and executing rehabilitation programs.

Numerous studies have been carried out to recognize the accident causes in construction. Different disciplines suggested different root causes for accidents by developing several causation models over the past decades. For instance, accidents occur due to human or judgment error, poor safety training, excessive stress, and unsafe behavior (Sawacha et al., 1999); Wolf and Brick (1996) pointed out inadequate site supervision and coordination of workers leads to accidents. Some of the major contributing factors to accidents are site congestion (Suraji et al., 2001), physical and mental disability of humans (Kletz, 1993), site hazards (Mitropoulos et al., 2005), poor work methods, improper planning, poor communication and organizational pressure (FISCA, 2006). An accident leads to indirect costs gained through medical treatment and workers' compensation. Also, it affects the productivity of business (Vigneshkumar and Salve, 2020) and emotional and psychological impacts workers involved and other co-workers (De saram and Tang, 2005). Therefore, health and safety problems become severe issues in the construction sector among the practitioners, academics, the government, and the public (Hoyle, 2009).

Globally, construction companies have started adopting best practices to improve safety in their industry. One of the best ways suggested by Gambatese and Pestana (2014) is by applying the safety practices most related to how to manage

safety issues. It is a method that addresses safety issues of workers and guides to provide a safe environment to workers on-site through workers' participation (Meltz, 2009). Similarly, the CII conducted a study and identified five effective safety techniques: alcohol and substance abuse programs, safety incentives, pre-project/task planning, safety training, and accident and near-miss investigation (Meltz, 2009). These safety techniques were revised by Hinze (2002) and exposed the significance of using best construction safety practices. They are grouped into nine groups as described in Table 1.

Howell and Ballard (1999) illustrate construction as a process of dynamic and uniqueness. According to them, lean construction tools could help reduce construction workplace accidents. Bashir (2011) suggests that lean construction tools will reduce workers' exposure to workplace hazards such as chemical, biomechanical, physical, noise, dust, and similar hazards on the construction site. Many construction professionals and academics have developed lean construction tools and effectively applied them across different stages of construction projects to improve safety performance (Abdelhamid and Salem, 2004). According to Salem and Zimmer (2004), the most developed lean construction tools are 5S (housekeeping), first-run studies, last planner system, error-proofing (Poka-yoke), and daily huddle meetings. The most commonly used lean construction tools are summarized in Table 2.

Table 2. Lean design tools (created from Bashir (2011))

Lean construction tools	Description
5S (housekeeping)	An approach to continue arrangements in the job site. It includes: Sort: Removing items from unwanted places and removing unused items. Set in Order: Arrangement of materials and tools for ease of use. Shine/Sweep: Sorting out the required materials and tools from unwanted ones to attain a safe working environment. Standardize: Maintaining the first 3S to enhance the process significantly. Self-Discipline/Sustain: Keeping the 5 S's in place.
First run studies	It is used to improve critical assignments to achieve continuous enhancement in production. The tool includes learning a job to be carried out, evaluating substitute work methods, and recognizing and sorting out the different roles in implementing the assignment.
Last planner system (LPS)	A planning approach based on obligation through the reliable use of techniques such as weekly work planning based upon reliable promises, make-ready look-ahead planning with constraint analysis, pull planning and learning based upon analysis of the planning system.
Error-proofing (Poka-yoke)	It is a way of minimizing or reducing defects that occurs on the worksite. A fault occurs when an error reaches a client, and this tool aims to prevent the mistake from becoming a fault.
Daily huddle meetings (DHM)	This meeting is communication among the team and the workers where they are straightly involved in problem-solving to increase job satisfaction. DHM is conducted to gather reports on the position of the work from when the previous meeting was held. Those reports are prepared based on issues affecting the process of work and working progress.

3. Integration of lean design tools and safety practices

From the above study, the possible interaction between safety management practices and lean construction tools to address the causes of accidents is shown in Figure 1. Further, this directs us to examine the significance of lean and safety practices to safety. Figure 1 illustrates the major accident causes identified through different studies and safety practices and lean tools considered appropriate in reducing those causes of accidents. Further, this directs us to examine the significance of lean and safety practices to safety.

3.1. Possible interaction of lean tools and causes of accidents

The accidents through poor work methods and excessive stress of workers could be reduced by integrating the work methods with workers' skills. Workers' empowerment in assignment scheduling helps reduce excessive stress and organizational pressure. Workers' physical and mental abilities could be reduced by linking work methods with workers' abilities. Logically, poor planning could be reduced by a weekly work plan. One of the major causes of accidents at

construction work is the unsafe behavior of workers and site congestion. Workers' coordination and involvement could reduce such accidents by creating site awareness among themselves through informal conversations and so on. Also, this could reduce the errors caused by poor communication and poor coordination among workers. Critical task planning through first-run studies could reduce poor planning, poor safety training, and human errors. Inadequate supervision could be reduced by regular visual inspection through error proofing (Poka-yoke). Accidents caused by site congestion and site hazards like dust, fumes, and so on could be reduced by cleaning the workplace through the 5S (housekeeping) technique.

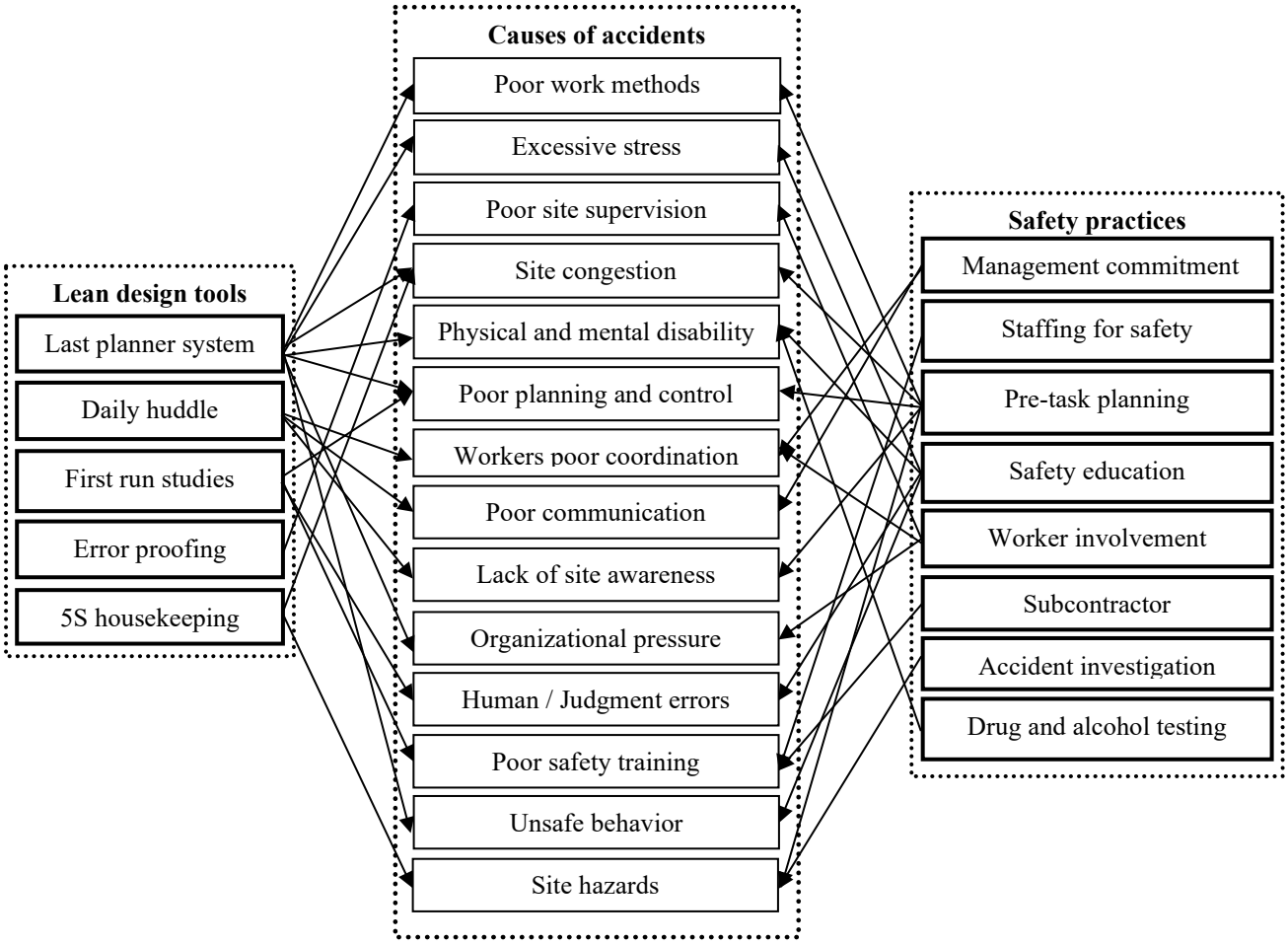

Figure 1. Interaction among lean construction tools and safety management practices and casues of accidents

3.2. Possible interaction of safety practices and causes of accidents

Management commitment to safety issues could potentially reduce poor coordination and communication among workers. The accidents through inadequate safety training could be reduced by the integration of methods of work with the ability of workers and their attitude. This could also reduce excessive stress, physical/mental disability, unsafe behavior, and human errors. The construction accidents caused by poor planning, site congestion, poor work methods, lack of site awareness, and site hazards could be reduced by preparing and maintaining the proper weekly work plan. Workers' involvement in projects helps reduce accidents caused by poor supervision, poor coordination of work, and organizational pressure. Accidents caused by physical and mental disabilities could be further reduced through drug and alcohol testing. Through subcontractor management, the worker skills and work methods could reduce the accidents caused by poor safety training. Pre-task accident/incident investigation could help in reducing site hazards.

4. Conclusion

From this study, five lean design tools and eight safety management practices were found to have a relationship with 14 safety issues that cause major accidents in the construction workplace. Among that last planner system and daily huddle meetings were the most important lean tools contributing a major role in improving safety performance in the workplace. Similarly, safety education and pre-task planning were the major contributing safety practices to reducing accidents in the workplace. From the overall relationship, it was observed that sincere management commitment from senior level to bottom level and pre-task planning integrated into the daily task would improve safety performance effectively on site. Further, workers' participation in safety commitments and education could help eliminate accidents in the workplace.

In this study, the different ways in which lean construction tools and safety practices impact safety issues in the construction workplace were identified through literature. The lean construction tools and safety practices possibly related to reducing these accidents were also identified. The finding can direct contracting organizations in using best safety practices and lean construction tools to promote safety in the construction workplace. Therefore, safety practices and lean construction tools can be adopted by the Indian construction sector to promote safety. Furthermore, government health and safety initiatives can incorporate lean construction practices to improve poor safety performance in the Indian construction industry.

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