




Research Article

Investigating the synergy between lean construction practices and post disaster management processes

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ABSTRACT

Lean aims to maximize value while minimizing waste. Lean practices are likely to reduce the number potential hazards and errors. The use of Lean practices in construction is essential to experience less hazards. Benefitting from Lean practices has gained much attention in the last decade. Especially, the destroying effect of hazards and accidents is of utmost importance in terms of seeking for better strategies. Within this context, Lean practices offer a wide variety of advantages and provide means for achieving greater success in projects. This study investigates the use of Lean practices in post disaster management. Since post disaster management includes the activities to help community in rebuilding, Lean tools and techniques might be employed to better handle post disaster management processes. The study also scrutinizes the integration of Lean practices with the post disaster processes and encourages the community to compete against the destroying effect of disasters thanks to using Lean tools and techniques. The main contribution of this study is that it introduces Lean practices to be used in the post disaster management processes, which might potentially remove safety concerns in construction sites up to a great extent.

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1. Introduction

Lean thinking is a term, which defines the conscious use of resources in an effective manner. One of the most important objectives of lean thinking is to minimize waste while maximizing value to the customer. Lean has first been appeared in the manufacturing industry. Lean Production System first emerged with the Toyota Company to offer high quality, wide variety and low-cost production to best address customer desires (Lean Enterprise Institute, 2019). After the considerable success of lean production in the automotive industry, the system was introduced to other industries.

Construction industry produces waste more than the other industries in the entire world (Meadows, 2011; Hu, 2011; Ajayi et al., 2016). Research studies implied different waste types in construction. For example, Bossink and Brouwers (1996) identified six sources of waste in construction namely the design, procurement, material, handling, operation, and residual. In another study,

Garas et al. (2001) introduced two main waste types as; (1) time wastes such as waiting periods, stoppages, clarifications, variations in information, rework, ineffective work, interaction between various specialists, delays in plan activities, and abnormal wear of equipment, and (2) material wastes such as over ordering, overproduction, wrong storage, wrong handling, manufacturing defects, theft or vandalism. Lean construction is therefore an effective means of production management for the project delivery, which allows designing and building capital facilities. Lean Construction is even beyond the lean production system in that it adopts the principle of minimizing waste and maximizing value while improving the total project performance in accordance with the customer expectations (Lean Construction Institute, 2019). The need behind the lean construction comes from the failure of mass production in the construction industry. Due to the changing needs of the customer, who desire variety, lean construction is essential to provide this variety.

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To minimize waste and maximize value, researchers have previously focused on several different lean construction methods. For example, Alshayeb (2011) clearly implied that modular construction is very effective reducing the waste and bringing resource efficiency. In his study, it was also demonstrated that modular is reusable, which evidences the essential function of modular construction. In Khanh and Kim's (2014) study, it was indicated that there are several waste factors in high-rise building projects and the determination of those waste factors is essential. Therefore, lean construction was proposed an opportunity for estimating the impacts of waste on overall project performance (Khadem et al., 2008). Unfortunately, the functional role of lean concepts in the construction industry has not been well understood yet by the construction professionals. Hence, a clarified roadmap, generic approach or introduction of a new concept is very important in order for the construction professionals to conceive the essential role of lean construction. On the other hand, application of lean technology into the construction industry provides a tremendous opportunity for the reduction of waste and increase in production (Marhani et al., 2013). The reduction of non-value adding activities has a significant contribution to the construction productivity improvement (Zhao and Chua, 2003; Han et al., 2011).

Disasters have devastating effects and result in serious defects. Hence, managing processes after disasters is of utmost importance in terms of facilitating the rebuilding activities. Especially, structural deformations and structurally damaged buildings after disasters put a high risk for the public health. To prevent, more innovative solutions and new techniques must be adopted. Within this respect, Lean practices shall be utilized to provide innovative solutions, prevent hazards or reduce the likelihood of occurrence of hazards. Several studies have already proven that there is a strong link between Lean and safer practices revealing that going leaner leads to experiencing less hazards (Mitropoulos et al., 2007; Bashir et al., 2011; Dehdasht et al., 2018). This study aims to put Lean practices forefront of disaster management strategy.

In addition to waste identification and waste reduction, this study aims to indicate the number of losses that the construction industry experiences every year. The studies have not yet proven an effective solution to overcome this barrier and successfully manage post disaster processes. Hence, the motivation of this study arose from this need to take the attraction towards the warning number of hazards and accidents in the industry and enlighten the need towards more innovative solutions. In this respect, the significance of this study is to motivate construction practitioners adopt Lean practices in their operations and benefit from them in post disaster management processes so as to limit or prevent losses.

2. Lean Construction

Lean construction is defined as "a clear set of objectives for the delivery process, aimed at maximizing performance for the customer at the project level, concurrent

design of product and process, and the application of production control throughout the life of the product from design to delivery" (Howell, 1999). Lean approach aims to maximize value to customer while minimizing waste. Hence, the main purpose of going Lean is to come up with more value for customer by using fewer resources. Going Lean is needed for the defective processes in mass production and craft production. Lean production was first introduced by Taiichi Ohno -a pioneer of Lean production- in the manufacturing industry in 1950s. Then, Lean was firstly used as a term by Krafcik in 1988. Toyota was the first manufacturing company that applied Lean in production and Lean production helped Toyota increase its profits with an upstream trend. Lean has started to gain attention in other major industries in time. Ballard and Howell (1998) first used the term "Lean Construction" to eliminate waste and increase productivity in construction projects. Lean construction has been implemented in several major projects to increase productivity and efficiency.

The efficiency of Lean practices for higher customer satisfaction and enhanced project performance was previously implied by several studies (Horman and Kenley, 1996; Khadem et al., 2008). Several studies have investigated lean and lean in construction. For example, Sacks and Goldin (2007) developed a lean management model for high-rise apartment buildings by adopting lean principles (i.e., pull scheduling, reduced batch sizes, and a degree of multitasking). The model intended to provide customized apartments, improved cash flow, and reduced apartment delivery cycle times. Aziz and Hafez (2013) concluded that lean projects are safer, easier to manage, completed sooner, cost effective, and are of better quality by referring to the impact of lean in minimizing waste in construction. Boyce et al. (2012) investigated the aspects of lean thinking and concluded that it helps to improve design phase of complex projects by emphasizing the essential function of collaborative planning process in highway design. Similarly, El-Reifi (2013) implied the positive impact of lean thinking adopted by design team in achieving higher customer satisfaction. Emuze and Smallwood (2013) conducted research on the interaction of lean, health and safety, and sustainability. Khanh and Kim (2014) emphasized the importance of identifying waste types in mid/high-rise building construction.

A major portion of studies in Lean has focused on identification of factors leading to a successful Lean implementation process. For example, the role of communication and management support regarding a successful Lean implementation was highlighted by Worley and Doolen's (2006) study. It was further studied that management commitment, employee autonomy, and transparent information flow are main Lean targets for a successful Lean management scheme (Scherrer-Rathje et al., 2009). Lean implementation was also mentioned to result in reduced lead time, work-in-process inventory, and manpower requirement (Singh et al., 2010). As previously implied in several studies, Lean approach is essential to experience higher productivity and efficiency in processes.

3. Post Disaster Management

Post disaster recovery is critical in terms of managing the rebuilding process. To facilitate, sound techniques and rescue technologies have to be put in place. This requires the use of innovative methods to help rebuild community leaders and smoothen the devastating effects in terms of fast recovery.

Even though pre disaster planning is important in not experiencing the losses, post disaster management is even more critical for the civil engineering. Especially, post-earthquake disaster management and structural assessment constitutes an important place in Turkish construction industry considering the earthquake prone zones in the country. Therefore, a well set action plan and preparedness for disasters are essential. Prieto and Whitaker (2011) indicated that post dis-

aster environment brings the need for changing construction and engineering requirements as well as economic and political framework. This requires a deep understanding of how a framework might be designed to handle the scenarios for post disaster environments. Gandage and Ranadive (2008) highlights the role of civil engineers in post disaster management. In their study, they identify that planning, setting up and maintenance of emergency relief camps are among the main responsibilities of civil engineers in disaster management.

Fig. 1 presents the traditional disaster management cycle. It shows the phases in both pre and post disaster. According to Fig. 1, it is observed that preparedness, mitigation, and prevention are the phases of pre disaster, whereas response, recovery, and reconstruction are the phases of post disaster.

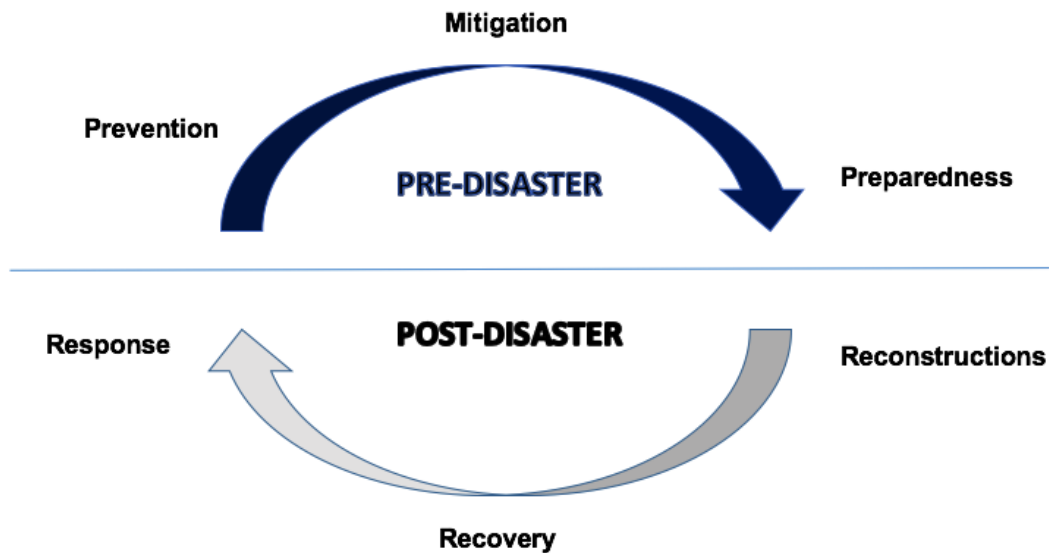


Fig. 1. Traditional disaster management cycle.

In this study, post disaster phases are investigated and Lean tools and techniques which might be used in those phases are identified accordingly.

3.1. Response

A well set emergency plan is developed at this phase of disaster management. Response actions are developed to overcome the impacts of economic losses and suffering. This phase encompasses the mobilization of emergency services and help first responders get in the disaster area as quickly as possible. The actions taken in the response phase include the activation of emergency operations centers, evacuation of populations at risk, opening of shelters, and provision of medical care and emergency rescue.

Response either starts immediately when an emergency case is on or right after an event occurs. Hence, response phase rather includes the short term plans regarding the execution of emergency operations plan and incident mitigation activities aiming to limit life losses, property damage, and unfavorable consequences. Some main response phase actions are listed but not limited to the following:

- Following well-set emergency procedures for making the alarm active, evacuating people, and having the disaster site safe
- Conducting observations regarding the source of the threat
- Reaching the disaster response team leader and get the trained salvage personnel
- Conducting a preliminary assessment of the disaster site to determine the extent of damage, supplies, services, and the equipment needed.
- Stabilizing the environment for surveillance and testing processes, isolation, or quarantine.
- Ensuring access to critical services such as law enforcement and public works.

The very first response task includes the assessment of the situation. The government is mainly the responsible party for the continuity of situation assessment for protecting the citizens and the property in the community. Therefore, government officials and responder teams should work collaboratively for the rapid assessment of the local case (IFLA, 2019).

3.2. Recovery

The activities in the recovery phases cover actions for getting the community back to normal conditions. These activities mainly consist of providing the basic services and repairing physical, social and economic damages. In the recovery phase, it is essential to provide financial assistance to those who were affected by the disaster as well as rebuilding the facilities damaged such as roads and bridges. It is also critical to sustain the mass care for human and animal populations. Recovery phase differs from the response phase for various reasons. Recovery is more intended to provide services for rebuilding of destroyed properties, re-employment, and repair of main infrastructure, whereas response involves actions for addressing immediate needs (Laemmermann, 2012).

Recovery phase starts following the emergency and some recovery activities might be concurrent with the response actions. Recovery involves coordination, development, and provision of service and site restoration plans for the impacted community in addition to reconstitution of government operations in terms of individual, nongovernmental and public and private sector programs. Some main recovery phase actions are listed but not limited to the following:

- Identification of needs and resources.
- Provision of housing and restoration.
- Provision of long term care for affected people.
- Developing mitigation procedures and techniques.
- Developing programs for preventing and controlling the effects of future incidents.
- Developing disaster preparedness measures and early warning systems for all sectors to minimize the number of losses (GFDRR, 2017).

The recovery phase sometimes takes longer than expected due to stabilization of all systems. Hence, it is important that the community and the government work in close coordination to overcome barriers regarding rebuilding of public health and safety.

3.3. Reconstruction

Reconstruction is the last phase of post disaster management and it involves two main steps namely the building housing units and restoring or building infrastructure. Housing is the first priority of disaster victims in several countries (Hidayat and Egbu, 2010). It was indicated that housing constitutes the majority of expenditure with 30-50% financial allocation in terms post disaster financing (Freeman, 2004). Hence, housing must be immediately addressed in post disaster environment to meet the needs of the victims. Sustainability is a critical parameter in reconstruction projects to reduce vulnerability for future disasters. Moe and Pathranarakul (2006) stated that reconstruction projects target to provide a unique product in a given duration for elevating the living conditions of persons rather than focusing on the profit.

Moe and Pathranarakul (2006) identified post disaster reconstruction phase as public project management

and introduced ten critical success factors, which must be addressed in disaster management. The critical factors are presented herein.

- Effective institutional arrangement: Decision making is speed up by the responsible government unit and authority line.
- Coordination and collaboration: Stakeholders' coordination and collaboration is a key factor for managing disasters.
- Supportive laws and regulations: The existence of supportive laws and regulations is a driver for the successful management of reconstruction phase in post disasters.
- Effective information management system: Existence of such system among key stakeholders results in successful outcomes after disasters.
- Competencies of managers and team members: Disasters are successfully managed when administrative, conceptual and technical skills are in place.
- Effective consultation with key stakeholders and target beneficiaries: Stakeholder consultation and communication with target beneficiaries are key processes in managing post disaster environment.
- Effective communication mechanism: This helps creating an environment, where stakeholder trust and cohesion is built and this eventually leads to higher project success in disaster management.
- Clearly defined goals and commitments by key stakeholders: Predetermined goals and responsive commitment helps reconstruction activities be completed with higher success.
- Effective logistic management: Technology, people, and expertise are part of the effective logistic management in disasters. This helps enhancing the capacity for coordination in organizations.
- Sufficient mobilization and disbursement of resource: Resource and mobilization is key for managing successful processes in disaster. This may be in the form of providing material, equipment, and workforce (Moe and Pathranarakul, 2006).

As the final phase of post disaster management, reconstruction is essential to help community recover and provide a safer environment to people.

4. Lean Practices in Post Disaster Management

This study investigates potential Lean construction practices that might be utilized in phases of post disaster management. This helps processes be conducted error free and provide a quicker rehabilitation after disaster. In a study conducted by Al Hattab and Hamzeh (2015), it was indicated that Lean practices reduce design errors. Similarly, Ko and Chung (2014) mentioned that design errors might be reduced with the Lean practices. In this respect, Table 1 presents relevant Lean construction practices along with their definition and presents relevance to post disaster management phases by summarizing how these tools and techniques be used in most effective manner.

Table 1. Lean construction practices in post disaster management.

Lean Construction Practices	Description	Relevance to Post Disaster Management Phases
Safety-by-Design (SbD)	SbD, also called as Prevention through Design (PtD) is a concept to apply methods for minimizing occupational hazards at the early phases of design process and aims to optimize employee health and safety through processes. The method encourages construction practitioners to design out risks in health and safety through design development (CDC, 2019).	Designing health and safety risks helps producing a less error prone environment and facilitates the post disaster management processes. SbD also involves the design of safer systems so as to minimize or prevent the effect of accidents. Especially, design of safer practices and processes results in less losses and speeds up reconstruction phase.
Last Planner System	Last Planner System is a management tool for implementing Lean in design and construction projects. The system is a collaborative planning technique for making planning processes more effective, reducing variability, and making work flow more reliable (Davidson, 2013). Last Planner System is also a tool to experience less safety breaches and schedule errors motivating collaborative work.	Collaborative planning is essential in post disaster management. Therefore, Last Planner System might be used effectively in response phase of post disaster management, where immediate care is needed and collaborative work is a must. This helps a quicker assessment of the disaster site and manage processes in coordination with the teams. Moreover, Last Planner System might be also practiced in the reconstruction phase bringing up effective communication and collaboration for rebuilding activities.
Mistake proofing	"Mistake proofing, or its Japanese equivalent poka-yoke is the use of any automatic device or method that either makes it impossible for an error to occur or makes the error immediately obvious once it has occurred." Mistake proofing might be used to fix processes, where human error leads to defective or error prone processes (ASQ, 2019).	Mistake proofing practices might be utilized in every post disaster management phases. In response phase, the mistake proofing tools (i.e. color coded tags) might guide people for the damaged zones and prevent the likelihood of unexpected consequences. In recovery phase, mistake proofing devices (i.e. warning sensory alarms) might be utilized to develop mitigation procedures and prevent the effects of future incidents. In reconstruction, mistakeproofing tools might play a vital role in providing quicker assessment of losses and helps rebuilding in terms of making defects clear.
Visual Management	Visual management is a strategy for benefitting from sensory systems through visual ability and controlling information flow and work through visual cues (Tezel et al., 2017). The use of visual tools are catalysts for warning systems.	Visual cues are of utmost importance in terms of facilitating work control. Hence, visual management is an effective Lean technique to prevent defective processes. The cues of visual management might be used in all phases in post disaster management. In response phase, the cues might be used for better explaining the emergency procedures to help for evacuation. In recovery phase, the cues might be used in developing the mitigation procedures for future incidents. In reconstruction phase, the cues might be utilized in tagging the restoration and disaster area for effective institutional arrangement.
Value Stream Mapping (VSM)	Value stream mapping is a material and information flow technique for comparing the current and future state of production (Rahman et al., 2012). It helps visualize all the processes for getting a product, service, and value adding project.	VSM might be used in response phase of post disaster management to visualize current and future state of emergency procedures. This might provide a quicker assessment of public needs and develop actions accordingly. VSM might be further utilized in reconstruction phase to speed up rebuilding processes by visualizing the current and future state.
5S	It is a workplace organization system to create a more efficient, safe, and clean working environment (Hiwale, 2018). It comes from the Japanese words translated as sort, straighten, shine, standardize, and sustain in English.	5S might be used in all phases of post disaster management since it is about providing an organized work environment. Hence, the disaster site might be organized properly so that the negative effects of disasters are minimized. Especially, in the reconstruction phase, it is essential to sort and standardize items for easy rebuilding.
Time and Motion Studies	A time and motion study refers to recording movements of an employee when accomplishing a task. The technique aims to increase productivity and efficiency (Lopetegui et al., 2014). These studies are of paramount importance to identify and eliminate non value adding activities.	In reconstruction phase of disaster management, time and motion studies might be used to detect non value adding activities to provide a better scheme of rebuilding processes. This speeds up the rebuilding activities and provide community a better environment in short term.

Kaizen	It is a Japanese management philosophy aiming to sustain continuous improvement. Kaizen helps enhancing efficiency and productivity at workplace resulting in higher quality and reduced costs (Shang and Pheng, 2013).	Kaizen might be used in all three phases of post disaster management since it aims to increase efficiency and productivity. The technique is applicable to response, recovery, and reconstruction phases during which efficient operations are in need.
Kanban	Kanban means “signboard or billboard” in Japanese. In Kanban technique, the flow of work is controlled through a set of cards, signals, and tokens (Tezel et al., 2017). It also helps teams work together effectively.	Kanban might be used in all processes of post disaster management. The use of informative cards, alarming signals and tokens would help save numerous lives in addition to quick rehabilitation of community. Therefore, Kanban systems are essential to inform community during response, recovery, and reconstruction phases.
Modularization and Prefabrication	Modularization and prefabrication is important in terms of reducing the risk of health and safety hazards. It also helps provide a faster delivery process (Gosling et al., 2016).	Modularization and prefabrication might be used in the reconstruction phase of post disaster allowing to a faster rebuilding process. It may be also utilized to reduce health and safety risks and protect community from a number of potential hazards.
Last Planner System	Last Planner System is a management tool for implementing Lean in design and construction projects. The system is a collaborative planning technique for making planning processes more effective, reducing variability, and making work flow more reliable (Davidson, 2013). Last Planner System is also a tool to experience less safety breaches and schedule errors motivating collaborative work.	Collaborative planning is essential in post disaster management. Therefore, Last Planner System might be used effectively in response phase of post disaster management, where immediate care is needed and collaborative work is a must. This helps a quicker assessment of the disaster site and manage processes in coordination with the teams. Moreover, Last Planner System might be also practiced in the reconstruction phase bringing up effective communication and collaboration for rebuilding activities.

5. Discussion

The construction is a risky business. Hence, the use of innovative systems and materials are in greater demand to sustain community health and safety. Lean construction is therefore an efficient strategy to provide best practices in construction projects. Since Lean aims to minimize waste, it offers various advantages for construction practitioners to deliver cleaner and safer environments to the clients.

Considering the destroying impacts of disasters, post disaster management constitutes an important part to remove those effects. Hence, it is essential that community leaders work in close coordination with innovators and team leaders to smoothen the negative impacts of disasters on public health and safety. In this respect, Lean tools and techniques are unique solutions in terms of providing a faster rehabilitation process for the community. Especially, the use of some Lean tools such as Mistake proofing devices and Kanban cards could save millions of lives and potentially reduce the negative consequences of disasters. Mojtahedi and Oo (2012) discussed the applicability of Lean in post disaster reconstruction and concluded that Lean elements help improve performance of post disaster reconstruction leading to higher quality in built environment and smoothened work flow. Hence, Lean tools are effective means of managing post disaster processes in terms of smoothening negative consequences of disasters. As a result, one might think that use of these tools shall be successfully integrated in the processes, where public health and safety is the highest priority.

In response phase of post disasters, following emergency procedures on time and stabilizing the environment for surveillance is critical for the timely provision of supplies, services, and the equipment. Traditional procedures are sometimes in lack of completing these tasks. Previous research implies that information and communication based technology must be put in place to better handle post disaster management processes (Ofori, 2002; Nishigaki et al., 2011). Therefore, Lean practices might be utilized in those processes to evacuate people more quickly from the disaster area and deliver services in a more organized manner.

In recovery of post disaster management, needs and resources are identified along with providing housing and restoration. Moreover, programs for preventing and controlling the effects of future incidents are developed. Therefore, several Lean tools and techniques would be efficient to use in those steps for a better recovery process. For example, use of Last Planner system and Kaizen technique could be effective in developing the programs and inform the community about future incidents.

In reconstruction phase, setting up an effective communication mechanism is essential. Moreover, faster rebuilding process might result in enhanced community satisfaction and faster rehabilitation. Therefore, Lean tools and techniques might be effective to rebuild the disaster environment and increase the efficiency of the processes. For example, color coded tags might be placed on the damaged structural areas to keep people away from the dangerous zones. Moreover, modularized and prefabricated construction elements might be used to have a quicker building process.

The use of Lean practices in processes help reduce the number of hazards. Considering the high number of hazards in construction, it is apparent that the industry needs more innovative and early warning tools for overcoming this challenge. This requires an in depth analysis of current tools and techniques and motivate practitioners to think of more beneficiary and effective systems to be set up at workplaces. Lean is not the best approach yet but it is clear that it has certain impact on reducing hazards. In this respect, several research studies pointed out to the interaction between Lean and safety (Nahmens and Ikuma, 2009; Bashir et al., 2011; Howell et al., 2017). Hence, it is essential practitioners beware of availability of Lean tools and techniques and utilize them when needed.

This study intends to reveal the strong tie between Lean construction practices and post disaster management phases. The link between Lean and post disaster was assessed in a few studies (Mojtahedi and Oo, 2012; Mojtahedi and Oo, 2017) but there has not yet been a broad research to reveal the interaction. Hence, this study aims to fill this gap by revealing the clear link between Lean practices and post disaster phases. In this respect, it provides a systematic interaction between those to encourage the use of Lean tools and techniques in response, recovery, and reconstruction phases.

6. Conclusions

This study investigates the use of Lean construction practices in the phases of post disaster management. In this respect, an in-depth literature review was conducted to reveal the practices applicable to use in response, recovery, and reconstruction phases. In the first part of the study, Lean construction studies were researched and best practices were highlighted. Then, post disaster management processes were considered to indicate main activities conducted during those processes. Several Lean construction practices such as use of Kanban systems, Last Planner system, 5S, VSM, and Kaizen were identified and the use of those was explained in relevant post disaster management phases. The study is a preliminary research for reflecting the interaction between Lean construction and post disaster management. Moreover, it also puts safety forefront of Lean construction practices in the post disaster management context. This might potentially impact the community for taking a step forward towards developing safety measures with the help of Lean tools. Furthermore, it is expected to guide construction practitioners to become familiar with Lean construction practices and benefit from them for a quicker rehabilitation after disasters.

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