POSSIBILITY OF APPLYING LEAN IN POST-DISASTER RECONSTRUCTION: AN EVALUATION STUDY

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ABSTRACT

Natural disaster management and the need to develop a resilient built environment for disaster-stricken community has always been the outstanding concern in many countries. Post-disaster reconstruction phase plays crucial role in recovery stage to cope with the impacts of natural disasters in reactive manner. The traditional views of post-disaster reconstruction activities have not been efficient and effective enough to develop shelters and permanent buildings on time, on budget and with acceptable quality. Furthermore, post-disaster reconstruction has often resulted in poor-quality built environment, waste of materials, delayed construction, and low-performed recovery. Therefore, contemporary tools and techniques should be applied by stakeholders in post-disasters reconstruction phase.

Lean construction philosophy and introducing the individual elements of the lean philosophy probably seems to improve the post-disaster reconstruction. This paper evaluates the possibility of applying elements of lean thinking and lean construction in post-disaster reconstruction phase. For this purpose, this study scrutinizes pertinent lean construction studies to borrow the benefits of quick mobilization, pull scheduling, Just-in-Time, and Six Sigma approaches in order to apply them in post-disaster reconstruction phase. Finally, we propose to integrate some feasible lean construction approaches with post-disaster reconstruction in order to eliminate waste, improve the quality of built environment, smooth the work flow and enhance the performance of post-disaster reconstruction phase in recovery stage of natural disaster management.

KEYWORDS

Lean construction, post-disaster reconstruction, disaster management

INTRODUCTION

Natural disasters are becoming more frequent, expensive and threatening globally. The worldwide economic expenditure associated with natural disasters has amplified 14-fold over the past fifty years (Guha-Sapir and Panhuis 2004; Masozera et al. 2007). Natural disasters like extreme weather, flooding, earthquake, bushfires, storms have devastating effects not only on socioeconomic, but also on built environment and infrastructure. Therefore, natural disaster management is inevitable for all communities around the world. Prediction, warning, emergency relief, rehabilitation, and reconstruction are the generic five phases of natural disaster management

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carrying out by stakeholders before, during or after natural disasters (Moe and Pathranarakul 2006). Although all of phases are integral in natural disaster management, the focus of this study is on reconstruction phase. Post-disaster reconstruction phase include providing immediate shelters, temporary housing, and permanent housing reconstruction (Johnson et al. 2006). Unfortunately, they reported that most of the post-disaster reconstruction tasks are planned in a rush and in a situation of almost total chaos. Many studies have also reported that poor quality, waste material, delayed construction time, inadequate supply chain planning, poor reconstruction planning, the use of low-skilled labours are common drawbacks of post-disaster reconstruction (e.g. Alexander 2004; Bolin and Stanford 1991; Chang et al. 2010).

Although Bertelsen and Koskela (2004) claimed that more than 300 papers presented in peer reviewed journals and conferences along with dozen reports and dissertations since 1992 to 2004, the role of lean construction has not been reviewed in natural disaster management. Lean construction philosophy and introducing the individual elements of the lean philosophy probably seems to improve the post-disaster reconstruction. The main objective of this study is to examine the possibility of applying lean in post-disaster reconstruction. The applied method in this study is to review some pertinent papers to borrow the potential benefits of lean approaches to apply them in post-disaster reconstruction. Therefore, the aim of this paper is to propose an integration of lean thinking and lean construction in post-disaster reconstruction phase of natural disaster management. We explore that the integration of lean approach and post-disaster reconstruction result in performance enhancement, waste reduction, improved quality of built environment, lower reconstruction cost, better use of human resources and agile recovery.

NATURAL DISASTER

Natural hazards such as floods, hurricanes, tornadoes, winter storms, earthquakes, tsunamis, volcanoes, and landslides are part of the world around us, and their occurrence is inevitable. Alexander (2000) defines natural hazards as extreme events that originate in the biosphere, lithosphere, hydrosphere or atmosphere. He also believes this term is very useful because of the fact that it distinguishes such phenomena from technological and social hazards. The natural hazard has been explained as the interaction between extreme physical phenomena and vulnerable human and environment (Alcantaraayala 2002; Alexander 2000; Smit et al. 2000).

The natural hazard becomes a natural disaster as soon as human beings, infrastructure, or other forms of tangible or intangible capital is threatened and/or destroyed by that hazard (Alexander 1997). He also described that a natural disaster seems to become rapid, instantaneous or profound impact of the natural environment upon the socio-economic system.

Centre for Research on the Epidemiology of Disasters (CRED) provided a more comprehensive definition of disaster (Guha-sapir et al. 2010, p.14), "a situation or event which overwhelms local capacity, necessitating a request to a national or international level for external assistance; an unforeseen and often sudden event that causes great damage, destruction and human suffering." CRED also defines that natural disasters are events that have natural causes and result in 10 or more mortalities, affect 100 or more people, or result in a call for international assistance or the declaration of a state of emergency. Munich Re, the world's largest disaster insurance company, predicted the cost of disasters worldwide will be exceeded $300 billion per year by 2050 (Freeman 2004).

NATURAL DISASTERS AND CONSTRUCTION PROJECTS

Natural disasters have devastating effects on built environment such as, roads, bridges, hospitals, schools, power plants, refinery plants, airports, ports and public facilities. Many scholars investigated the transportation network vulnerability against natural disasters (e.g., Hoshiya et al. 2004; Menoni 2002; Sohn 2006). Roads and bridges are most likely to be damaged by these hazards, may be of great importance as transportation hubs for post event disaster response and recovery efforts (Wood et al. 2002). Ports and harbours are particularly vulnerable to natural disaster such as earthquakes, landslides, and tsunami inundation because they are located in sea level areas (Wood et al. 2002).

The share of built environment and construction projects' damages in natural disasters are nearly $10 billion per annum worldwide (Freeman 2004). For many natural disaster-prone countries, the ability to cope with the devastating impacts of disasters before, during, and after calamities is a key component to maintaining the resilient built environment. Nonetheless, building and construction are complex processes involving various actors, especially in non-residential buildings. Different stakeholders may optimize their own part of the process, but there is often no system to optimize the total building process (Roberts 2008).

NATURAL DISASTER MANAGEMENT

Disaster management comprises plans, structures, and arrangements in a thorough way to respond to the whole spectrum of emergency situations. It is interchangeably used with a term emergency management (Moe and Pathranarakul 2006). It is noted that disaster management covers wider scope than crisis management (Kumar 2000), where crisis is a situation faced by community which they have not ample ability to tackle it with normal routine procedures (Booth 1993; Loosemore and Hughes 1998). United Nation International Strategy for Disaster Reduction (2004) has adopted concept of disaster risk management into four phases; hazard identification, mitigating adaptations, preparedness planning; and recovery (short-term) and reconstruction (long-term) planning. According to Moe and Pathranarakul (2006), disaster management includes five phases:

- *Prediction.* Mitigation and preparedness are two main elements of prediction phase. Structural measures and non-structural measures could be taken in this phase.
- *Warning.* In this phase identification of risky situation and providing timely and effective information play crucial role.
- *Emergency relief.* Assistance during or immediately after a disaster constructs the basic concept for emergency relief phase.
- *Rehabilitation.* Decisions and actions after a disaster with the purpose of restoring or improving the living condition of stricken community are firmly required in this phase. Rehabilitation is a short-term measure.

- *Reconstruction.* This phase is a long-term measure focusing on reconstructing the damaged facilities and environment.

There are two different approaches to cope with the devastating impacts of natural disasters (Moe and Pathranarakul 2006). First, tasks that are planned and conducted before the disaster impact with an aim to effectively minimize the adverse impacts of the disasters are called proactive approach. On the other hand, activities of responses and recovery are regarded as reactive approach. Figure 1 illustrates the disaster management phases, relevant activities and approaches.

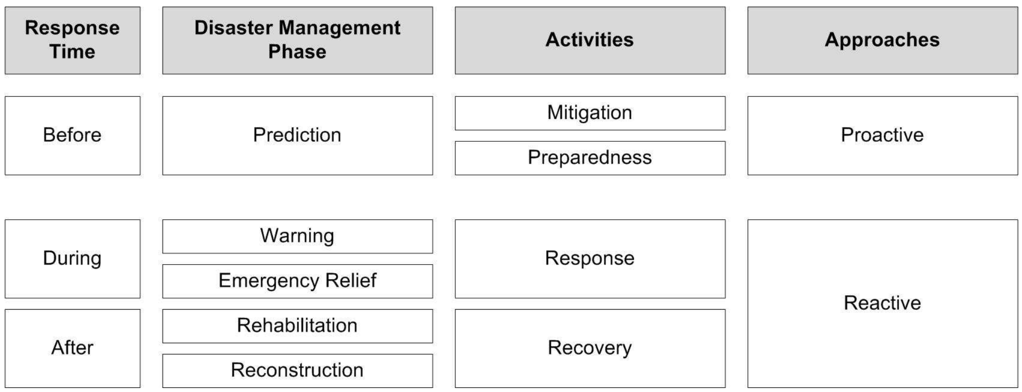

Figure 1: Disaster management phases and approaches, source: Moe and Pathranarakul (2006)

POST-DISASTER RECONSTRUCTION

One of the most critical natural disaster management phases is reconstruction phase occurring after natural disasters. This phase includes recovery activities which classified as a reactive approach in natural disaster management. There is often a great emphasis on mitigation, readiness and response activities, with poor understanding and little consideration given to the implications of recovery (Masurier et al. 2006). What does differentiate post-disaster reconstruction from traditional construction environment? Greater degree of coordination with policy and legislation is required for post-disaster reconstruction, different communities and stakeholders will be involving in post-disaster reconstruction (e.g., Government, NGO, and insurance companies). Moreover, the aim of post-disaster reconstruction is to produce non-profit oriented unique product in certain duration to elevate living condition of people (Masurier et al. 2006, Moe and Pathranarakul 2006, Roberts 2008). Indeed, post disaster reconstruction can be used as an accelerator to improve people's lives and make communities safer (Alexander 2004). Reconstruction should thus be regarded as a more prominent element in post-disaster programming. Nevertheless, when reconstruction programs are attempted, the particular challenges that they pose tend to be underestimated; planning is often poor and coordination between agencies is difficult (Barakat 2003). He claimed that there are five distinct approaches to post-disaster reconstruction:

1. Providing transitional and temporary housing (shelter).
2. Repairing damaged housing.
3. Building new housing.
4. A 'building yard' approach, whereby communities do the rebuilding.

5. A 'finance facilitation' approach.

Previous studies have reported that post-disaster reconstruction measures often result in poor-quality housing, supplies do not arrive on time, slow delivery, high cost per unit, expensive to maintain, requires skilled labour to assemble, requires good foundations that may prove expensive (e.g., Comerio 1997; Chang et al. 2010; Ganapati and Ganapati 2008).

Furthermore, reducing waste material in post-disaster reconstruction phase is a main concern for stakeholders (Pheng and Chuan 2001; Pheng and Hui 1999). The poor reconstruction process itself can lead to disasters (Ofori 2004). He also claimed that many governments in developing countries have been undertaking massive post-disaster reconstruction programmes at great cost.

LEAN CONSTRUCTION AND POST-DISASTER RECONSTRUCTION

Over the past three decades, outstanding ameliorations in performance and productivity of manufacturing sectors have been detected. Nowadays, manufacturers, in particular automobile industries, are using less manufacturing space, less human efforts. They have been producing the products in less cost, less time, and more quality in compare with products couple of decades ago. A part of these improvements have been occurred by the advent of cutting-edge technology, but a new production philosophy, "Lean Production", has a significant contribution to production improvements' revolution (Russel and Taylor 2011).

In 1992, Luari Koskela, introduced the lean production philosophy to construction tasks. Consequently, lean construction theory developed (Alarcon 1997; Ballard et al. 2010; Tommelein et al. 1999) and later, Koskela (2000) presented the theoretical framework for lean construction based on operation management theories. Lean construction principles and practices have been developed in planning and controlling stream. Lean construction is an approach to cope with all construction tasks to minimize waste, time, and effort to produce the maximum possible amount of value (Koskela 2000). On the other words, lean construction means doing more with less – less inventory of materials, fewer human resources, less space, less waste of materials, optimum time of construction, less cost variances and high quality.

Lean construction philosophy and introducing the individual elements of the lean philosophy probably seems to improve the post-disaster reconstruction. Although many different lean techniques and tools have been applied in production and construction management as lean approach over the past thirty years by scholars, some techniques such as quick mobilization (Russell and Taylor 2011) Just-in-Time (e.g., Alarcon 1997; Pheng and Chuan 2001; Pheng and Hui 1999), pull scheduling (e.g., Han et al. 2008; Thomas et al. 2003; Tommelein 1998), and Six Sigma (e.g., Alarcon 1997; Han et al. 2008; Linderman et al. 2003) have been remarkable tools to reduce waste, to decrease schedule variance, and to improve quality in construction and built environment. Figure 2 shows the proposed integration of lean elements and post-disaster reconstruction phase. This integration is known as lean recovery in this paper. The respective four lean elements are examined in turn in the next section.

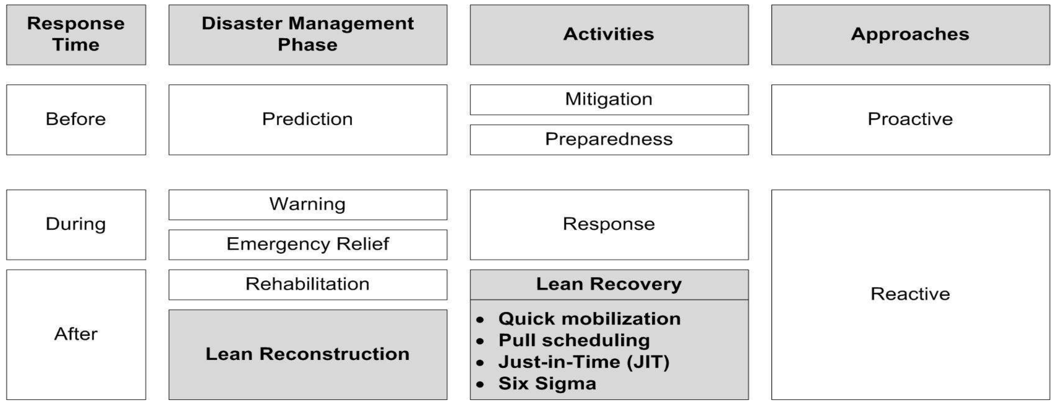

Figure 2: Integrated post-disaster lean reconstruction approach adapted from Moe and Pathranarakul (2006)

QUICK MOBILIZATION AND RECONSTRUCTION TIME REDUCTION

Shortened construction lifecycles in natural disaster recovery phase is very crucial for alleviating the effects of stricken people. The first action in recovery phase should be completing the reconstruction tasks on time. For this purpose, a wiser approach is to make reconstruction lean and agile. One of the lean strategies in shortening reconstruction phase is to focus on mobilization times for all stakeholders. Main activities for quick mobilizations in post-disaster reconstruction are as follows:

1. Separate internal mobilization from external mobilization: Internal mobilization could be taken by general contractor, but external mobilization refers to site establishment could be taken by sub-contractors. In order to act lean and agile in reconstruction phase, all stakeholders involved in construction tasks should separate their mobilization activities from each other. Moreover, sub-contractors should mobilize in advance or in parallel with general contractor. Application of this concept in production systems have reduced machines' setup time by 30 to 50% (Russell and Taylor 2011).
2. Converting internal mobilization to external mobilization: To make sure the preliminary activities, such as tendering, design phase and standards, are prepared in mitigation phase before natural disasters.

PULL SCHEDULING AND RECONSTRUCTION COMPLETION ON TIME AND ON BUDGET

Construction work traditionally is scheduled by Critical Path Method (CPM). It determines the relationship among activities, duration and resources are then assigned to each individual task. In this so-called "push-driven" approach, each activity passively waits for its resources to become available, e.g., by being released upon completion of predecessor activities. Therefore, overloaded resources and availability of resources waiting in buffer result in poor productivity in construction planning. Tommelein (1998) claimed that the traditional, push-driven approach to scheduling prior to the start of construction with no corrective re-scheduling as work progresses leads to process inefficiencies and less-than-optimal project performance. Hence, she proposed pull scheduling as a lean approach to construction planning in order to improve the performance of construction process, i.e., to complete the construction tasks on time, on budget and with acceptable quality. Pull scheduling, as a lean construction tool, have been applied to assist project managers to complete construction projects on time (Han et al. 2008; Thomas et al. 2003; Tommelein 1999). Pull scheduling technique focuses on resources selection and resource allocation to construction tasks from resource queue or pool in order to minimize resources' wait time in queue. The selection of resources is not only to satisfy the need of predecessor activities, but also to fulfil the need of work-in-progress (WIP) and successor queues and activities (Tommelein 1999).

In post-disaster reconstruction phase, it is common that supplies do not deliver on time, there are long delays in construction completion time, and resources waste time is also distinguished. Pull scheduling is thus a useful tool to improve the performance of post-disaster reconstruction phase in natural disaster recovery stage. Reconstruction planning should be carried out before strikes in order to anticipate future needs and reduce the time required to set reconstruction tasks.

JIT AND POST-DISASTER RECONSTRUCTION PRODUCTIVITY IMPROVEMENT

Just-in-Time (JIT) is a method of pulling work forward from one process to the next. This technique first was introduced by Ohno and his fellow workers at Toyota (1988). JIT reduces WIP inventory, reduces production cycle times, and reduces in flow variation (Alarcon 1997). JIT has been used in logistic management in construction projects to improve the productivity. This technique also helps to provide the right materials, in right quantities and quality to eliminate the waste on work sites (Pheng and Chuan 2001; Pheng and Hui 1999). Under the JIT concept, waste is defined as anything that does not add value to the final product, excess inventory is also regarded as waste. Waiting time, inspection time and time to detect defects are also considered waste (Pheng and Chuan 2001).

Pheng and Hui (1999) applied JIT approach for site layout to improve productivity and quality, to eliminate waste on site, to control inventory coming into the site and within the site, and to smooth work flow. In order to have a smooth delivery, waste elimination, minimum storage on site and improved productivity in post-disaster reconstruction phase in natural disaster management, it appears that JIT is an instrumental approach. Stakeholders who are involved in post-disaster reconstruction need to be educated in JIT and be guided along during the entire reconstruction process. In occurrence of disasters, there is a considerably large pick in terms of demand, increased load means more waiting. In this situation, the fundamental of queuing theory can play important role to decrease waiting time (Bertelsen and Sacks 2007). Consequently, variability and waiting time reduction results in waste reduction (Koskela and Vrijhoef 2001) by taking advantage of queuing theory.

LEAN SIX SIGMA AND RECONSTRUCTION QUALITY ENHANCEMENT

The poor-quality of erected buildings is another main area of concerns in post-disaster reconstruction phase for stakeholders. In order to minimize or eliminate this predicament, lean construction strategy should be taken by stakeholder before and during reconstruction. For lean systems to work well, quality has to be extremely high. Constructing poor-quality shelters and buildings and then having to rework or reject them is a waste that should be eliminated.

Although many scholars have applied quality management techniques in lean construction (Alarcon 1997; Green and May 2005), novel approaches such as Lean Six Sigma has not been widely applied in construction projects as a lean approach. Six Sigma is statistics based methodology to make significant reductions in customer-defined defects rates in an effort to remove effects and faults from every process (Han et al. 2008; Linderman et al. 2003). Han et al. (2008) suggested that a combination of Six Sigma and lean construction result in both productivity and quality improvement at the same time. To verify the suggested methodology, they studied two case studies to observe the performance changes based on the Six Sigma principle. They showed that the construction performance was improved as the sigma level advanced by enhancing the condition of critical total quality. Lean Six Sigma (also known as Lean Sigma) integrates Six Sigma and lean systems. Lean concentrate on eliminating waste and creating flow while Six Sigma reduces variability and enhances process capabilities (Russell and Taylor 2011).

The application of Lean Six Sigma in post-disaster reconstruction most likely improves the performance of construction process. Lean Six Sigma reduces the total project cost by maintaining the optimum resource buffer and eliminates the unnecessary resources. Thus, it results in waste materials reduction and the quality enhancement of buildings and shelters in post-disaster reconstruction phase.

CONCLUSIONS

The poor planning, ad hoc decision making, haphazard recovery, poor quality of built environment, waste of material, environmental damages, long reconstruction life cycle, and excess cost are the most distinguished predicaments in post-disaster reconstruction phase. In order to eliminate or lessen these issues, this paper explored the feasible strategies to combine post-disaster reconstruction and elements of lean thinking and lean construction for the improvement of the reconstruction processes and operations in natural disaster recovery stage. The proposed lean construction framework for post-disaster reconstruction consists of four lean elements. They are: (i) Quick mobilization (ii) Pull scheduling, (iii) JIT, and (iv) Lean Six Sigma. Further study could focus on empirical study of proposed integrated post-disaster reconstruction. Moreover, the usage of lean thinking has a great potential of study in natural disaster management framework. It could pave the way to shift the reactive approach to proactive approach in disaster management context.

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