

Review of LEED Pilot Credit: Trajectories for PtD

Suchismita Bhattacharjee
University of Oklahoma
Norman, OK

Designers have the most prolonged involvement in any construction project, and thus have the most opportunities to influence the project. National Institute of Occupational Safety and Health (NIOSH) has started the initiative of 'prevention through design' (PtD) to address occupational safety and health needs in the design process to prevent/minimize the hazards downstream. US Green Building Council (USGBC), who introduced Leadership in Energy and Environmental Design (LEED) to address environmental impacts of buildings, has now introduced its first pilot credit for implementation of PtD in a design and construction project. LEED encourages designers to perform safe constructability reviews between schematic design and design development phase to identify the ways in which safety and efficiency could be achieved during construction. Such reviews along with general contractors, subcontractors and suppliers will help to decide on the most suitable trajectories for PtD, such as prefabrication, use of less hazardous materials and systems, construction engineering, site logistics etc. Further USGBC suggests that such review along with LEED credits can help to identify additional trajectories for PtD to improve construction workers' safety and health. Using this as the point of departure this study attempts to identify jobsite safety impacts associated with LEED certification, the rate of success of the new LEED PtD pilot program to address those impacts, and predict trajectories of PtD that could help alleviate the identified safety issues associated with achieving certain LEED credits.

Keyword: Prevention through Design, LEED, Trajectories of PtD,

Introduction

With the increase in development, adoption and diffusion of technology, buildings built in the last few decades are becoming increasingly resource intensive and also have detrimental impact on the environment (Agency), 2009). In an effort to reduce this impact of buildings on the environment, US Green Building Council (USGBC) introduced Leadership in Energy and Environmental Design (LEED) in 1998. In less than two decades LEED had become the most widely used rating system for third-party verification of green buildings. According to USGBC, approximately 1.85 million square feet is certified by LEED daily (USGBC, 2016b). Though LEED has been widely acknowledged for being so successful in elevating or reducing the environmental impact of buildings, it has also been held responsible for not addressing issues related to jobsite safety of construction workers until now (Dewlaney, Hallowell, & Fortunato III, 2012; Fortunato III, Hallowell, Behm, & Dewlaney, 2012).

Construction industry has historically been one of the most demanding and dangerous industries due to its complex and dynamic nature. This fact is reflected in the data published by United States Bureau of Labor Statistics which shows that construction industry sector recorded 738 fatal work injuries in 2011, which is almost 16% to all the work related fatalities . It has been posited by the scholars that many safety hazards of the construction industry are "designed into" construction projects (Behm, 2005b; John A. Gambatese, Behm, & Hinze, 2005). Design determines the configuration and constructability of a facility and to a large extent determines how the facility will be constructed. The configuration of the facility can influence (both positively and negatively) the safety of the constructors. Korman (2001) proposed the concept of designing for safety, an intervention which is gaining popularity in the construction industry. Recently, the National Institute of Occupational Safety and Health (NIOSH) has started the initiative of 'prevention through design' (PtD) to address occupational safety and health needs in the design process to prevent/minimize the hazards downstream (Howard, 2008).

LEED had been successful in addressing, the major concern of environmental impact of built environment, by encouraging designer and contractors to implement strategies that would reduce the environmental impact. Thus, the expectation arose that if LEED was successful to alleviate some of the environmental concerns of construction industry, it could also play a role in addressing the issues related to jobsite safety and hazard. Additionally, several researchers have also identified several potential hazards which might arise from the extra construction work required for constructing the green buildings and achieving LEED credits (Dewlaney et al., 2012; Fortunato III et al., 2012). In response to the high industry demand for a safe and healthy jobsite environment for workers, recently LEED introduced pilot credits for implementing PtD strategies to address worker's health and safety during construction process (USGBC, 2016d).

This paper attempts to identify jobsite safety impacts associated with LEED certification, the rate of success of the new LEED PtD pilot program to address those impacts, and predict trajectories of PtD that could help alleviate the identified safety issues associated with achieving certain LEED credits.

Prevention through Design

Designers have the most prolonged involvement in any construction project, and thus have the most opportunities to influence the project. NIOSH lead a national initiative on PtD to highlight the role of designers in improving safety of construction workers. Szymberski (1997) posited that the ideal time to consider construction safety is during conceptual and preliminary design phases, as a significant portion of the ability to influence is lost if it is left for consideration only during construction phase. With the current view of safety management in the US construction industry where the responsibilities for workers' safety are burdened on the contractors, the ability to effectively design for elimination or substitution of hazards are considerably reduced (Behm, 2005b). A growing number of industry leaders throughout the world have started recognizing PtD as an effective mean to enhance safety of construction workers.

LEED Buildings & Construction Safety

USGBC, a non-profit organization established in 1993, "is committed to transforming the way our buildings are designed, constructed and operated through LEED - the top third-party verification system for sustainable structures around the world" (USGBC, 2016a). LEED 1.0 was the first green building rating system in US introduced by USGBC in the year 1998. Following that 12 buildings across US was certified within the first two years of their inception (USGBC, 2013). In the next six years, i.e. from 2000 – 2006, USGBC roughly registered 60 projects a month on average, which increased to around 700 per month by the end of 2008 (USGBC, 2016c). In the meantime, several researchers had identified the impact of LEED buildings on construction safety, which had been a point of concern for several years, due to the increasing number of occupational hazards caused by the complexity in building design and construction (Dewlaney et al., 2012; Fortunato III et al., 2012; John A. Gambatese et al., 2005; Rajendran & Gambatese, 2009; Rajendran, Gambatese, & Behm, 2009). Researchers introduced the concept of "sustainable construction safety and health" due to lack of a significant difference in safety performance between LEED and non-LEED projects and LEED's negligible consideration for construction workers' safety and health (Rajendran & Gambatese, 2009). The former researchers further conducted a pilot study to assess the positive or negative impacts of a LEED Gold certified green building on construction workers' safety and health (Rajendran et al., 2009). Further Fortunato et al. (2012) identified safety risks which could possibly arise from construction strategies implemented to achieve LEED certification.

LEED Pilot: Prevention through Design

USGBC LEED recently introduced an opportunity to achieve a credit on a pilot basis for addressing strategies to implement PtD in a construction project. The goal of this introduction of PtD credit is "to support high-performance cost-effective employee safety and health outcomes across the building life-cycle through early attention to safety and health hazards" (USGBC, 2016d). This will encourage people to identify and use opportunities to achieve safe and healthy working conditions beginning at the pre-design and throughout the design phase. LEED encourages designers to perform safe constructability reviews between schematic design and design development phase to identify the ways in which safety and efficiency could be achieved during construction. Such reviews along with general contractors, subcontractors and suppliers will help to decide on the most suitable trajectories for PtD, such as prefabrication, use of less hazardous materials and systems, construction engineering, site logistics etc. Further USGBC suggests that such review along with LEED credits can help to identify additional trajectories for PtD to improve construction workers' safety and health. Using this as the point of departure this study identified trajectories of PtD that could be implemented to overcome the safety hazard associated with the LEED credits.

Method

Several researchers have concluded that significant improvement in health and safety of construction work conditions can be achieved if safety is integrated into the building design and construction process (Behm, 2005a; John A Gambatese, 1998, 2000; Hecker, Gambatese, & Weinstein, 2005; Hinze & Wiegand, 1992; Manuele, 2013; Rubio, Menéndez, Rubio, & Martínez, 2005). Toole & Gambatese (2008) identified few trajectories to integrate safety measures into building design and construction process. This study builds on the already identify trajectories by Toole and Gambatese (2008) and identifies few additional trajectories through literature review which would be necessary to overcome the identified safety hazards associated with LEED credits.

Following a literature review, 3 published articles were identified, where authors associated construction safety hazards with the work required to achieve certain LEED credits (Dewlaney et al., 2012; Fortunato III et al., 2012). The primary type of data analysis for this study was content analysis and constant comparison analysis. Content analysis is an orderly, replicable method to pack together a set of data into fewer selected categories based on a clear set of rules. It is a useful technique to sift through large volumes of data and categorize them in a more methodological and systematic manner (Robson & McCartan, 2016). Instead of directly observing, or interviewing for the purpose of data collection, the researcher reviewed past peer reviewed publications to identify specific safety hazards associated with the construction process to achieve certain LEED credits as shown in Table 1 and the identified trajectories of PtD. Qualitative data analysis began with the coding of each individual safety hazards as listed in past literatures and the trajectories of PtD. Further the author identified few new trajectories for PtD which are necessary for certain specific safety hazards.

Findings and Analysis

From the review of past literature 10 credits that are currently a part of LEED v4 were identified as causing potential safety hazards (Fortunato III et al., 2012). Table 1 lists each of the 10 identified LEED credits and the potential safety hazards as identified by Dewlaney (2012). Through literature review the author identified four trajectories for PtD as described by Toole & Gambatese (2008) 1)prefabrication 2)use of less hazardous materials and systems 3)construction engineering, and 4) spatial investigation and considerations, which may be implemented to alleviate the additional construction safety hazards associated with LEED credits. For the safety hazards which could not be alleviated with any of the four identified trajectories for PtD, the author proposed additional trajectories.

LEED Credits & Associated Safety Hazards

The LEED credits that creates potential hazardous environment on construction jobsite were identified for a study performed by Fortunato III et. al (2012). The researchers interviewed the lead designer and the construction project manager of 6 LEED certified projects. Further another study performed by Delaney (2012) identified a total of 14 LEED credits associated with the increase in unsafe conditions., of which 12 LEED credits were same from the previous study. The following section provides a detailed description of the LEED credits that has the potential to create unsafe jobsite condition

1. **Sustainable Sites (SS): Heat Island Reduction-** To achieve the LEED credit for 'Heat Island Reduction' with high reflectance roof the building has to have roofing materials that have a higher Solar Reflective Index(SRI). In the survey study performed by Fortunato III et. al (2012) three LEED projects used white thermoplastic olefin (TPO) membrane instead of traditional black ethylene propylene diene monomer (EPDM) membrane to achieve the 'Heat Island Reduction' credit for roof. The white TPO when compared to the traditional EPDM, are significant heavier, brilliantly bright in sunlight and extremely slippery when wet. All of the above mentioned criteria of TPO create potential conditions for slip, trip, fall and overexertion hazard.
2. **Energy and Atmosphere (EA): Enhanced Commissioning –** This credit calls for additional testing and inspection of building systems by a third party commissioning agent, which requires for ascending and descending on ladders, thus increasing the potential for fall hazard.
3. **Energy and Atmosphere (EA): Optimize Energy Performance –** The two most common methods adopted to achieve this credit are heavy continuous insulation along building shell and evaporative chillers (Fortunato III et al., 2012). Both the afore mentioned techniques results in increased labor hours or heavy material lifting which in turn can be the potential causes of hazards due to fall and overexertion.
4. **Energy and Atmosphere (EA): Renewable Energy Production –** The most commonly used strategies to achieve this credit is the installation of photovoltaic (PV) panel on roofs which has been proved to be a cause for struck-by and fall hazards because the panel are typically installed by cranes at a height (Gerhold, 1999).
5. **Material Recycling (MR): Construction and Demolition Waste Management Planning –** This particular credit though is very beneficial for the environment, can be a reason of potential abrasion, laceration, sprains, strains or exposure related hazards as the workers have to pick up and sort materials manually. Often construction waste is associated with airborne gypsum, which is identified as the major cause of silicosis (Butler et al., 2000).

6. **Indoor Environmental Quality (IEQ): Additional Enhanced IAQ Strategies –** This credit requires separate ventilation for rooms with the possibility of reduced air quality, which thus requires full-length drywall and additional fans and ductwork. It also requires installation of additional sensors for advanced IAQ monitoring, which can cause potential fall hazards, as workers might have to climb tall ladders for the installation of the sensor. This additional construction work exposes the workers to hazards related to overexertion (Fortunato III et al., 2012).
7. **Indoor Environmental Quality (IEQ): Low-Emitting Materials- Adhesives and Sealants –** Similar to the Construction IAQ Management Plan, this credit can also be associated with mixed hazard assessment. The lower quality of the low-emitting adhesives and sealants results in rework and increase in the hours of exposure of construction workers for additional site preparation thus exposing them to negative health of silica inhalation (Linch, 2002). Contradictorily, low-emitting adhesives and sealants reduces workers' exposure to volatile organic compound which has been proved to be harmful to human body.
8. **Indoor Environmental Quality (IEQ): Construction IAQ Management Plan (During Construction) –** Mixed hazards were identified to have associated with the different strategic adopted to achieve this credit. During an interview of the project managers and lead designers of some LEED projects, few of them mentioned about fall hazards associated with the installation of plastic coverings at the end of the air ducts. Additionally, another interviewee responded that fully ventilated interiors and restricted use of acetones reduced workers' exposure to poor indoor air quality.
9. **Indoor Environmental Quality (IEQ): Interior Lighting – Lighting Control –** This requires the installation of individual controls and occupancy sensor. The process to achieve this credit has been associated with fall hazards, as workers might have to climb tall ladders for the installation of the occupancy sensors (Fortunato III et al., 2012).
10. **Indoor Environmental Quality (IEQ): Daylight 75% of Spaces –** This credit requires the installation of large windows which has been associated with hazards related to fall and overexertion.

Trajectories for PtD from Past Literature

Prefabrication: Prefabrication is the process of manufacturing at specialized facility, where numerous materials are put together to form a modular part of an ultimate installation. In addition to the several other advantages of prefabrication as listed by past researchers (Gibb & Isack, 2003; Goodier & Gibb, 2007; Ho, 2001; Hsieh, 1997; Pasquire, Gibb, & Blismas, 2005; Yee & Eng, 2001a, 2001b), it is also effective in reducing the chances of jobsite hazards. One of the major advantages of prefabrication is reduced labor hours of construction, and labor productivity gain, which in turn reduces the exposure of the workers towards possible occupational hazards. As described by Toole and Gambatese (2008) prefabrication can reduce jobsite hazard level as it allows to shift the location of the work to a lower hazardous environment and it also allows work to be shifted from the field to the factory thus allowing the use of safer, automated equipment in improved environments.

Hazardous Material and Systems Controls: Certain commonly used construction materials can be hazardous due to its problem with indoor air quality (IAQ), excessive flammability or skin reactions. Owners and designers are becoming aware that these commonly used hazardous materials can often be replaced with less harmful materials and at comparable cost. This is more applicable for coatings, adhesives, and cleaners, which are associated with air quality, flammability and skin hazards

(Weinstein, Gambatese, & Hecker, 2005). It is suggested that designers should make the decision on different building materials based on its hazard level. Similar to hazardous materials, designers are also encouraged to consider the hazard level of various building systems. As research identifies alternative materials with reduced hazard level, it is expected that designers will consider that along with cost, quality, and schedule when deciding on building materials and systems.

Construction Engineering: At numerous instances during a construction project, engineering is necessary to plan or execute certain tasks, such as material handling tasks using crane lifts, soil bearing analysis for support of construction equipment, temporary structures etc. According to Toole and Gambatese (2008), if this engineering task is not performed by design engineers during the design phase, then they might be performed by unqualified personnel or not performed at all. Several times engineering tasks like cave-in protection, scaffolding, falsework, or crane picks are designed and implemented without any engineering expertise. Often these task fail thus leading to jobsite fatalities. Thus it is extremely important for designers and engineers to perform this task during the design phase and not leave it in the hands of the unexperienced.

New Trajectories for PtD Proposed by Author

Site Logistics: Site logistics planning can also play important role in occupational safety and health of the workers. Layout of material staging area, assembly area, entrance/exit route of delivery vehicles, working areas of crane, emergency refuge area, areas for stockpiling dirt, and similar decisions may have significant effect on the movement of workers and equipment onsite during construction. Three dimensional planning of the site logistics can be significantly helpful in planning the positioning of all the above mentioned entities to determine the risk of people involved in the construction process. The engineer can be specifically helpful in identifying the service area of the crane, the load movement area, etc. that can be crucial inputs for the site logistics planning.

Pre-Construction Process Planning: It has been the author's experience that majority of the focus during the pre-construction phase stays on finding answers to the questions 'what' and 'who'. While answers to the 'what' questions help the construction team identify the scopes and quantities of work, answers to 'when' direct them to the overall sequence and timing of the tasks. However, minimal effort is expensed on finding answer to the question 'how'. The planning team can examine the different options of available tools and equipment that can be best suited for the specific purpose. This also offers them an opportunity to look into the demand and capacity of the resources (workers and equipment) as there are evidences that pushing the capacity of the resources might create fatigue in them or push them to the brink of adopting unsafe behaviors (Rasmussen, Pejtersen, & Goodstein, 1994). With the increased use of alternative project delivery methods such as Design-Build and Integrated Project Delivery, there are more opportunities for designers to work with the contractors and have an active role to play during the pre-construction process planning. Moreover, decisions related to the construction processes will be more effective if taken during the pre-construction phase as any changes due these decisions can be reflected in the documents.

Success of LEED – PtD Credit in Address the Safety Hazards

The section below list all the safety hazards identified earlier which are associated with LEED credits along with the LEED-PtD assessments to address the identified hazards. The association between the identified trajectories for PtD and the identified safety hazards are listed in Table 1. This will provide new direction to LEED on how to overcome the hazards through LEED-PtD credits.

- Fall Hazard: The increased exposure to fall hazard can be addressed by properly assessing and minimizing the need for work at height as suggested by USGBC through LEED-PtD (USGBC, 2016d). Fall hazard can also be addressed through properly assessing sequencing issues from ahead of time.
- Overexertion Hazard: Since overexertion hazards are due to the overload for the worker, it can be greatly minimized by assessing construction safety and sequence issues.
- Struck-by Hazard – Struck-by hazard can be addressed through the design of proper site logistics. Unfortunately, this hazard is currently not addressed by the suggested LEED-PtD assessment plan.
- Abrasion and musculoskeletal injuries – Though generalized strategies to addresses hazards like abrasion and musculoskeletal injuries are not be listed in LEED-PtD assessment, but instead suggests to assess worker handling construction wastes, and incorporate measures.
- Airborne Contaminants: LEED-PtD suggests specific assessment plans to address hazards related to airborne contaminants.

Table 1: Safety hazards associated with LEED credits and how it is addressed by LEED-PtD or proposed trajectories of PtD

LEED CREDITS	STRATEGIES	HAZARDS	LEED – PtD CREDIT	PtD TRAJECTORIES
SS: Heat Island Effect—Roof	White TPO roof or clay tiles with appropriate SRI	Increased exposure to fall, strip or slip hazard	Assess and minimize the need for work at height.	Site Logistics
		Increased overexertion hazard	Assess construction safety and sequence issues	Pre-Construction Process Planning
EA: Enhanced Commissioning	Additional testing and inspection of systems	Increased exposure to fall hazard	Assess and minimize the need for work at height	Construction Engineering
EA: Optimize Energy Performance	(1) Heavy continuous insulation of building shell (2) Evaporative cooling chiller	Increased overexertion hazard	Assess construction safety and sequence issues	Pre-Construction Process Planning
		Increased severity of a fall hazard	Assess and minimize the need for work at height	Construction Engineering
EA: Renewable Energy Production	Photovoltaic panel on facility roof	Increased exposure to Fall	Assess construction safety and sequence issues	Construction Engineering
		New struck-by or-against of materials being lifted onto roof		Site Logistics
MR: Construction and Demolition Waste Management Planning	Diversion of waste into different dumpsters by material	Exposure to abrasion	Assess construction worker handling of construction wastes, and incorporate measures	Pre-Construction Process Planning
		Exposure to musculoskeletal injuries		Prefabrication
				Site Logistics
		Exposure to struck-by or-against		Site Logistics
		Exposure to airborne contamination	Assess the utility of low-emitting materials	Hazardous Material and Systems Controls
IEQ: Additional Enhanced IAQ Strategies	Separate ventilation and additional sensor installation	Increased exposure to overexertion hazards	Assess construction safety and sequence issues	Pre-Construction Process Planning
		Increased exposure to fall hazard	Assess and minimize the need for work at height	Construction Engineering
IEQ: Additional Enhanced IAQ Strategies	Installation of separate ventilation systems and sensors	Increased exposure to overexertion hazards	Assess construction safety and sequence issues	Pre-Construction Process Planning
IEQ: Low-Emitting Materials-Adhesives and Sealants	Poor adhesive quality requires more frequently rework	Silica exposure hazard	Assess IAQ management plan	Hazardous Material and Systems Controls
			Assess the utility of low-emitting materials	
IEQ: Construction IAQ Management Plan	Plastic covering of duct ends during construction	Increased exposure to fall hazard	Assess and minimize the need for work at height	Construction Engineering
IEQ: Interior Lighting Control	Individual controls and occupancy sensors	Increase exposure to fall hazards	Assess and minimize the need for work at height	Construction Engineering
IEQ: Daylight 75% of Spaces	Larger windows to allow for more sunlight into the facility	Increased overexertion hazard	Assess construction safety and sequence issues	Pre-Construction Process Planning

Conclusion

Construction industry has historically been one of the most demanding and dangerous industries due to its complex and dynamic nature. NIOSH lead a national initiative on PtD to highlight the role of designers in improving safety of construction workers. LEED had been so successful in addressing, the major concern of environmental impact of built environment, by encouraging designer and contractors to implement strategies that would reduce the environmental impact. Thus, the expectation arose that if LEED was successful to alleviate some of the environmental concerns of construction industry, it could also play a role in addressing the issues related to jobsite safety and hazard. Additionally, several researchers had identified the impact of LEED buildings on construction safety, which had been a point of concern for several years, due to the increasing number of occupational hazards caused by the complexity in building design and construction (Dewlaney et al., 2012; Fortunato III et al., 2012; John A. Gambatese et al., 2005; Rajendran & Gambatese, 2009; Rajendran et al., 2009). Early 2016 USGBC LEED introduced an opportunity to achieve a credit on a pilot basis for assessing the potential safety hazards and implementing PtD in a construction project. USGBC suggests that such assessments along with LEED credits can help to identify additional trajectories for PtD to improve construction workers' safety and health. Using this as the point of departure this study identified trajectories of PtD that could be implemented to overcome the safety hazard associated with the LEED credits. After thorough review of past researches and LEED V4 credits, the study identified 10 LEED credits that can be associated with safety hazards related to fall, strip, slip, abrasion, overexertion and or exposure to chemicals or fumes. Review of the suggested LEED-PtD assessments against the identified safety hazards indicated that all of the hazards except struck-by are being addressed by LEED. Upon further review of the trajectories for PtD, the study identified five trajectories for PtD, that would encompass and address all the identified safety hazards associated with LEED credits. Site Logistics and pre-construction process planning were proposed as the two new trajectories which can avoid potential safety hazard situation related to fall, strip, slip, struck-by and overexertion.

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