LEED Credits

How They Affect Construction Worker Safety

By John Gambatese and Nicholas Tymvios

IN BRIEF

- **There is a growing awareness that green design and construction practices may affect construction worker safety.**
- **An in-depth review of the LEED-NC rating system for new construction found that many of the credits do not influence construction worker safety, while other credits may produce either a positive or a negative effect.**
- **In some cases, attaining the LEED-NC credits may increase the amount of exposure to, or extent of, hazards that already exist on the construction site.**
- **Suggested modifications to the LEED-NC credits have been developed to mitigate their effect on construction worker safety and aid in ensuring that green buildings are also safe to construct.**

The number of buildings certified by the U.S. Green Building Council's (USGBC's) Leadership in Energy and Environmental Design (LEED) rating system continues to grow. According to USGBC (2010), more than 34,600 LEED- certified and -registered construction projects have occurred as of August 2010. An increasing number of federal, state and local agencies are augmenting their policies to mandate that the design and construction of public buildings in their jurisdiction be LEED certified or equivalent (Environment and Human Health Inc., 2010).

To achieve LEED credits, owners, designers and contractors incorporate green features into site selection and project design, and complete the construction work using green materials and practices. Examples of green elements are the use of alternative materials containing low levels of volatile organic compounds (VOC), the use of reclaimed materials from demolished buildings, the implementation of green roofs and the use of alternative sources of energy to power the facilities. For example, one site used temporary protection of HVAC ducts during construction as part of the LEED efforts on a project to eliminate contaminants within the HVAC system and improve indoor air quality. The intent is to reduce the project's energy and environmental impacts.

As the number of LEED-certified projects grows, there has been increasing awareness and concern about the potential effect that green features have on occupational safety and health (OSH). Compared to traditional design and construction practices, green features may pose additional or new risks to worker safety and health through the introduction of alternate materials, as a result of different or additional work, or by creating an expanded or unintentionally hazardous work environment.

Based on practical experience, Walsh (2011), indicates that some aspects of buildings related to LEED, such as increased use of windows and skylights, installing photovoltaics on roofs, and recycling building materials that are heavy or contain protruding rebar or sharp edges, have the potential to increase safety hazards. Research corroborates this experience with regard to skylights and installing photovoltaic panels (Gerhold, 1999).

The potential for green features to create OSH hazards also came to light during the construction of the City Center project in Las Vegas, NV. While the project attained multiple LEED certifications for its design and construction efforts, it experienced numerous fatalities along with concerns about safety and health related to the construction methods designed to achieve LEED credits (Gittleman, Haile, Stafford, et al., 2009; Silins, 2009). The extent to which green design and construction has expanded throughout the construction industry in-

John Gambatese, Ph.D., P.E., is a professor in the School of Civil and Construction Engineering at Oregon State University. He earned a B.S. and an M.S. in Civil Engineering from the University of California at Berkeley and a Ph.D. in Civil Engineering from the University of Washington. He has worked in industry as a structural engineer and as a project engineer for construction. He started his current position in 2000 after 3 years on the faculty at University of Nevada, Las Vegas, and 1 year as an acting assistant professor at the University of Washington. Gambatese has taught courses on construction contracts and specifications, construction safety and productivity improvement, planning and scheduling, structural analysis and design, temporary construction structures and engineering economics. He has performed research and published numerous articles on construction worker safety, sustainability, constructability, innovation, construction contracting and life cycle properties of civil engineering facilities. He is a member of the American Society of Civil Engineers (ASCE) and ASSE, and actively participates on ASCE's Prevention through Design Committee, Construction Site Safety Committee, Constructability Committee, and Construction Research Council.

Nicholas Tymvios is a Ph.D. student in the School of Civil and Construction Engineering at Oregon State University. His educational background includes a B.S. and an M.S. in Civil Engineering from Purdue University with emphasis in structural engineering. After completing his M.S., he worked in industry at Tymvios Bros. Ltd., a steel fabrication company in Cyprus, for 4 years.

dicates that OSH risks could extend well beyond the City Center project.

NIOSH has proposed the need to consider worker safety and health as part of green design and construction. Through its Prevention Through Design (PTD): Green, Safe and Healthy Jobs initiative (CDC, 2010), NIOSH is bringing awareness to the issue and provides informational support to those involved in construction projects. At the NIOSH-sponsored Making Green Jobs Safe Conference, held in December 2009, industry experts discussed the connection between sustainability and OSH. Discussions resulted in high-priority action items in different industry sectors, including construction. Following are the top recommended themes for making OSH an integral part of the green economy:

- Make OSH a priority by leveraging the purchasing power that government and industry already have, whether via contracts or grant authority.
- Integrate OSH data collection and monitoring into codes and standards of practice that already have wide support so that improved OSH protections also become standard practice.
- Improve the data collection process to identify and understand safety and health risks and use those data to more effectively promote OSH investment.
- Create better methods and better standard references that can be used by OSH professionals to better protect workers.
- Invest more time and resources to train exposed populations and to increase awareness among workers who are being exposed to controllable risks.
- Fix broken regulations (i.e., where gaps in safety and health coverage mandates exist).
- Conduct market research to create new motivators that will inspire owners, employers and workers to make OSH a priority that cannot be ignored (Department of Health and Human Services, 2011).

Given the construction industry's experience and leadership to date, the authors conducted an investigation of the connection between the LEED rating system for new construction (LEED-NC) credits and construction worker safety and health. USGBC lists the credits included in the LEED-NC 2009 version (LEED 3.0) of the rating system, which can be found at **www.usgbc.org/DisplayPage.aspx?CMSPageID=220** by clicking on the "Checklist" quick link.

As a pilot study, this research aims to identify areas of potential effect that LEED-NC credits have on construction site safety and health, and if applicable, suggest ways in which the credits could be modified and/or augmented to benefit safety and health on construction sites. The researchers formed the following research questions to guide the study:

- Which credits within the LEED-NC rating system potentially affect, either positively or negatively, worker safety and health on construction sites?
- How do green design and construction features implemented to attain LEED-NC credits affect, either positively or negatively, worker safety and health on construction sites?
- To what extent is LEED-NC affecting construction worker safety and health throughout the construction industry?
- How can the LEED-NC rating system be modified or augmented to benefit construction worker safety and health on LEED-rated projects?

The study was limited to the design and construction of buildings, commensurate with the LEED-NC rating system, and to buildings currently under construction or recently completed that employed the LEED-NC rating system.

Previous Research & Current Practice

The need to include OSH as part of sustainable design and construction, and the extent to which LEED credits address construction site safety and health, are topics discussed in the literature. It is recognized that the social aspect of sustainability encompasses OSH and, therefore, construction site safety (Valdes-Vasquez & Klotz, 2010). Similar to protecting and conserving environmental resources, sustainability values the stewardship of human resources.

Behm, Lentz, Heidel, et al. (2009), assert that for green buildings to be considered sustainable, construction safety and health concepts must be integrated into upstream considerations. To do so, the authors recommend that the effect of specific green building elements on construction worker safety and health be determined, and that the concept of PTD be integrated with sustainable practice. Schulte, Heidel, Okun, et al. (2010), provide examples of how green design features affect construction safety and those who are working in green jobs. The hazards described in these examples can be eliminated or mitigated through PTD practices. In support of these authors, Toole and Carpenter (2011) make the connection between PTD and sustainability, stating that safety is a part of the social aspect of sustainability and is affected through such upstream factors as contracting requirements, designing for accessibility, community involvement and consideration of infrastructure resilience.

In a recent study comparing the safety performance of LEED-rated and non-LEED-rated building projects, Rajendran, Gambatese & Behm (2009), make an initial attempt to examine LEED's impact on project safety. In their analysis of 86 building construction projects, the researchers found suggestive, but inconclusive evidence of a statistically significant difference in recordable incident rates of the LEED and non-LEED projects studied. No difference was found between the lost-time case rates of the two study groups. How-

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LEED 2.0 Credits Increasing Risk in Construction

1) Sustainable Sites (SS) 6.2: Stormwater Design—Quality Control
2) SS 7.2: Heat Island Effect—Roof
3) Water Efficiency 2: Innovative Wastewater Technologies
4) Energy & Atomosphere (EA) 1: Optimize Energy Performance
5) EA 2: On-Site Renewable Energy
6) EA 3: Enhanced Commissioning
7) Materials & Resources 2: Construction Waste Management
8) Indoor Enviromental Quality (IEQ) 1: Outdoor Air Delivery Monitoring
9) IEQ 3.1: Construction IAQ Management Plan—During Construction
10) IEQ 4.1: Low-Emitting Materials—Adhesives and Sealants
11) IEQ 5: Indoor Chemical and Pollutant Source Control
12) IEQ 6.1: Controllability of Systems—Lighting
13) IEQ 8.1: Daylight and Views—Daylight

ever, the authors propose that for any building to be labeled as sustainable, it must experience better construction safety performance than the average building project.

The concern about LEED's influence on construction safety and health also can be deduced by observing the total number of LEED credits that are directly related to OSH in the LEED-NC 2009 (LEED 3.0) rating system. A total of 15 of the 110 credits in LEED 3.0 explicitly consider human health. However, these 15 credits are contained in only the Indoor Environmental Quality (IEQ) section of the rating system. As a result, a new construction project can achieve platinum certification, the highest certification available, with 80 credits or more, without satisfying a single credit of the 15 allocated to human health (Environment and Human Health Inc., 2010). The credits that explicitly address OSH are summarized below (Chen, 2010). It should be noted that these credits are the same as in previous versions (LEED 2.0, 2.1 and 2.2).

- IEQ 3.1: Construction Indoor Air Quality Management Plan—During Construction
- IEQ 3.2: Construction Indoor Air Quality Management Plan—Before Occupancy
- IEQ 4.1: Low-Emitting Materials—Adhesives and Sealants
- IEQ 4.2: Low-Emitting Materials—Paints and Coatings
- IEQ 4.3: Low-Emitting Materials—Flooring Systems
- IEQ 4.4: Low-Emitting Materials—Composite Wood and Agrifiber Products

Other credits besides these affect OSH without specifically addressing OSH. In a study involving eight LEED-rated projects, Fortunato, Hallowell, Behm, et al. (2011), found a total of 13 credits within the LEED 2.0 rating system that potentially increase the risk to worker safety and health during construction (LEED 2.0 Credits Increasing sidebar). With regard to whether the increased risk was new to the site or simply the same as risk already present, the researchers report that the "most consistent and repeated finding was that there is an increased duration of exposure to known, high-risk work environments." Potential injuries related to repetitive motion, heavy lifting, awkward positions and other causes of overexertion injuries were increased on the case study projects. The researchers also identified five credits that help to decrease safety and health risk during construction (LEED 2.0 Credits Decreasing sidebar).

Previous research has identified LEED credits that can potentially have a positive or negative effect on OSH. The present research aims to validate and support past studies by performing an independent review of the LEED rating system credits, and by presenting case studies of four additional construction projects on the Oregon State University (OSU) campus in Corvallis, OR. The present study departs from previous research in that it includes a determination of the effect of LEED on OSH across the construction industry, beyond the case study projects. In addition, the present study extends previous research by taking the additional step to suggest modifications to the LEED credits in order to improve OSH.

Research Plan & Methods

To answer the first three research questions, the researchers undertook the following separate activities. The results were then used to answer a fourth research question and develop recommended modifications to the LEED-NC credits to improve OSH on construction projects.

Review of LEED-NC Rating System Credits

Researchers reviewed the current LEED-NC rating system to establish the extent of inclusion of OSH in the various credits. A description of each credit and its intent was obtained from the USGBC website, as well as the required actions and documentation needed to achieve each credit (USGBC, 2008). Using the researchers' knowledge and experience in construction safety and health, each credit was reviewed and identified as having positive effect, no effect or negative effect.

Case Studies of New Projects

For some LEED-NC credits, various green design and construction elements may be selected to attain the credit. This research activity was aimed at evaluating how specific project features intended to attain a LEED credit could impact construction site safety and health. Four building projects on the OSU campus were used as case study projects for the research. These buildings were selected for their proximity, accessibility, status of completion and desire to achieve LEED certification. The projects, each of which employed the construction manager/general contractor (CM/GC) method of project delivery:

- **Oregon State University Energy Center (OSUEC).** Completed in 2009, the 21,500-sq-ft facility produces electricity and steam for campus needs. Its steel-frame, with a brick and steel panel facade, contains a cogeneration energy system that combines heat and electricity generation. Rating system: LEED Version 2 (OSU, 2010d).
- **Linus Pauling Science Center (LPSC).** This four-story, steel-frame, mixed-use building has 105,000 sq ft of space for classrooms, offices, an auditorium and chemistry labs. It was completed in September 2011 after an approximately 2-year

construction schedule. Rating system: LEED Version 2 (OSU, 2010a).

•**Hallie E. Ford Center (HFC).** This three-story, concrete-frame building with masonry exterior includes offices and conference rooms. It has a total floor area of 18,000 sq ft. Rating system: LEED Version 2 (OSU, 2010b).

•**International Living Learning Center (LLC).** This five-story center has reinforced concrete, mixed-use building and includes a 356-bed residence hall, 26 classrooms, a general purpose auditorium, faculty offices for OSU's international program and retail space. Completed in September 2011, the building has a total floor area of 148,000 sq ft. Rating system: LEED Version 3.0 (OSU, 2010c).

The researchers obtained the plans and specifications for each project from the contractors. The contractors contacted each project's LEED accredited professional (LEED AP), and meetings were arranged between each LEED AP and the researchers. At the meetings, the LEED AP reviewed each credit sought on the project and listed the actions taken to achieve each credit. The LEED AP then assessed each credit with respect to OSH and described any potential risks. To facilitate the interview process, the conversations were recorded, and subsequently transcribed and analyzed to identify the actions taken for each credit and any potential risks to OSH.

Assessment of LEED-NC's Effect on OSH Throughout the Construction Industry

LEED practices on additional projects were assessed to determine the extent to which those credits identified as "reducing or increasing risk to OSH" were achieved on projects across the U.S. This was done to estimate the national effect of LEED-NC on construction safety and health. The investigation was performed on a representative sample of LEED-NC certified buildings. Only buildings certified using the LEED 2.0, 2.1 and 2.2 rating systems were selected because of the insufficient number of buildings certified using the newer LEED 3.0 rating system at the time the research was conducted. A random sample of new construction projects that were built under LEED 2.0, 2.1 and 2.2 was chosen from the USGBC website (USGBC, 2010).

Statistical Methods Used

For this study, the sample size was determined using the simple random sample without replacement (SRSWR) technique with Formula 1 (Lohr, 1999):

$$n_o = \frac{z\alpha/_2 S^2}{e^2}$$

Where
n_o = sample size, z = z-ratio, α = precision,
e = margin of error and S^2 = variance

For surveys such as the present survey where proportions are measured, the value of the precision (α) is usually set at 0.05 and the value for the margin of error (e) is 0.03 (Lohr, 1999). Increasing the margin of error reduces the sample size required, while decreasing the margin of error requires a larger sample. With a precision of 0.05, the z-ratio has a value of 1.96. The variance (S^2) is approximated by Formula 2 (Lohr, 1999), which is a maximum and more conservative value when the proportion of the variable under investigation (p) equals 0.50.

$$S^2 \approx p(1\text{-}p)$$

Due to time and funding constraints on the study, a margin of error of 0.10 was chosen for the investigation, which limits the required size of the random sample to 100 projects. The precision was kept at 0.05. These values of α and e ensure that the percentage calculated for each credit will have a margin of error of ±10% with a probability value of 95%. It should be noted that while increasing the margin of error to 0.10 enables the study to meet time and funding constraints, it also affects the results associated with this portion of the study. A larger margin of error reduces the level of confidence that the final results are accurate. For the present study, it means that there is a greater chance that the actual percentage of projects which have attained the LEED credit is different from that calculated.

A total of 100 projects were randomly selected from the USGBC website. The credits for each project were accessed using the LEED certified building directory on the USGBC website. The directory contains a summary matrix for each project that shows the LEED credits achieved by the project to gain its certification. Each project matrix was accessed and the achieved credits recorded in a spreadsheet for analysis. Summary matrices for classified projects were not available. Therefore, whenever a classified project was selected in the simple random sample process, it was replaced by another randomly selected project from the list using SRSWR, until the requisite information from 100 projects was collected.

Results

Review of LEED-NC Rating System Credits

The review of LEED-NC credits revealed both positive and negative potential effects on OSH. Most credits do not affect OSH any differently than the design and construction practices present on non-LEED buildings. For credits that pose no additional risk, the work required to achieve these credits is of the same nature in a LEED-certified building as on a non-LEED building. That is, achieving some credits requires contactors to perform exactly the same work as in non-LEED build-

LEED 2.0 Credits Decreasing Risk in Construction

1) IEQ 3.1: Construction IAQ Management Plan—During Construction
2) IEQ 4.1: Low-Emitting Materials—Adhesives and Sealants
3) IEQ 4.2: Low-Emitting Materials—Paints and Coatings
4) IEQ 4.3: Low-Emitting Materials—Flooring Systems
5) IEQ 4.4: Low-Emitting Materials—Composite Wood and Agrifiber Products

Photo 1: Recycling bin for cement products at one of the case study projects.

Photo 2: Increased window areas may create additional fall hazards during construction.

Photo 3: Rooftop solar panels adjacent to the roof edge can be hazardous to workers installing and maintaining the panels.

PS EXTRA

For complete lists of the additional LEED credits, visit www.asse.org/psextra.

ings. Sixteen credits fit into this category (for the complete list, visit **www.asse.org/psextra**):

- Sustainable Sites (SS) Prerequisite 1: Construction Activity Pollution Prevention;
- SS 3: Brownfield Redevelopment;
- SS 4.2: Alternative Transport—Bicycle Storage and Changing Rooms;
- Energy and Atmosphere Prerequisite 3: Fundamental Refrigerant Management;
- EA 1: Optimize Energy Performance;
- IEQ 7.1: Thermal Comfort Design.

Some LEED credits require the use of materials from sources that utilize sustainable practices or are within a specified distance from the site. For these credits, materials quality, type and properties do not necessarily change and, therefore, there is no change in the effect on OSH. Eight credits fit into this category:

- MR 3.1 and 3.2: Resource Reuse;
- MR 4.1 and 4.2: Recycled Content;
- MR 5.1 and 5.2: Local Regional Materials;
- MR 6: Rapidly Renewable Materials;
- MR 7: Certified Wood.

The installation of additional sensors and switches to monitor and optimize energy and material use is required to meet some of the LEED credits. In some cases, plumbing, mechanical or electrical fixtures may be replaced with similar fixtures that meet LEED requirements for energy efficiency. These types of modifications do not affect OSH risk. Ten credits fit into this category (for the complete list, visit **www.asse.org/psextra**):

- SS 8: Light Pollution Reduction;
- Water Efficiency (WE) 1.1: Water Efficient Landscaping;
- WE 3.1 and 3.2: Water Use Reduction;
- IEQ 6.1: Controllability of Systems—Lighting.

Nine of the LEED credits do not affect OSH at all since they address the selection of the site prior to construction and various features and processes that occur after construction is complete. Examples of these are:

- SS 1: Site Selection;
- SS 2: Development Density and Community Connectivity
- SS 4.1: Alternative Transportation—Public Transportation
- SS 4.4: Alternative Transportation—Parking-Capacity;
- EA 3: Enhanced Commissioning.

The review of LEED credits found some that can have a favorable effect on OSH. That is, if these credits are attained, the workplace environment will be free of OSH risks that are typically present on non-LEED projects. Those credits that aim to encourage the use of low VOC compounds (IEQ 4.1, 4.2, 4.3, 4.4) are examples of such credits. Similarly, IEQ Prerequisite 2 for Environmental Tobacco Smoke (ETS) Control, which is aimed at the completed facility but also adopted by contractors for the construction phase of the building, favorably impacts construction worker health.

The Heat Island Effect credits (SS 7.1 and SS 7.2) are beneficial to worker safety and health as they require the use of materials that pose lower health exposure risks. For example, to reduce the heat island effect, one option is to utilize more landscaping and less concrete and asphalt that can expose workers to health risks due to the chemicals and fumes associated with these building materials. Similarly, for roofs, depending on the roofing material chosen, the work can have equal or less health risk compared to non-LEED buildings.

In the review of LEED credits, the researchers also identified credits that can potentially increase OSH risks. For example, SS 5.1: Site Development—Protect or Restore Habitat, where the requirement to protect trees on the jobsite can create traffic congestion, force the overlapping of pedestrian and vehicle pathways, and limit available space on the construction sites. Credits that require contractors to increase recycling on the construction site (MR 2.1 and MR 2.2) increase the time and effort required to separate and dispose of the construction waste material. Photo 1 shows an example of a recycling bin for cement products at one case study project.

As another example, IEQ 8.1: Daylight and Views—Daylight and IEQ 8.2: Daylight and Views—Views, require the rooms to have more daylight. To achieve these credits, the amount of window area is typically increased and more sky-

lights are added on the roof, both of which create additional fall hazards during construction. For example, Photos 2 and 3 show the exteriors of two case study buildings with extensive window areas. Also note in Photo 3, the presence of rooftop solar panels adjacent to the roof edge, which poses a hazard to workers installing/maintaining panels.

Case Studies of New Projects

Table 1 summarizes the input from LEED APs about risks associated with LEED credits. The case study projects did not all use the same version of the LEED-NC rating system. However, the LEED credits are very similar in the different versions, and their effects on OSH risk are shown in Table 1. Credits not shown in Table 1 were deemed by LEED APs to have equal risk in LEED and non-LEED buildings. For LEED Credits MR 1.1, 1.2, and 1.3, the information was not applicable since the investigated buildings were entirely new construction and did not require any building reuse.

The case study investigation also included a review of injury data from the chosen projects. For this analysis, the researchers examined how the incidents were related, if at all, to the green features in the building. In addition, the researchers attempted to identify whether the green features could be improved in order to reduce OSH risk for construction and maintenance workers. For the structures that were still under construction, the investigation only accounted for the incidents recorded prior to conducting the research. A summary of incidents at each site follows:

- At the LPSC project, three OSH incidents occurred prior to the study: one near-miss and two injury incidents requiring medical tratment. In the first injury incident, a plumber was lifting pipe in the building's basement and attaching the pipe to the ceiling. Lifting the heavy pipe overextended the muscle and caused a torn bicep. The other injury incident involved a worker walking on the metal deck. The worker lost his footing when walking over rebar lying on the deck. The worker fell and cut his knee on the rebar. The near-miss incident occurred when a worker was drilling into the ceiling above and unintentionally drilled through a temporary power cord. Fortunately he was not injured. None of the incidents involved green features of the building.
- The contractor for the HFC project stated that the site had no incidents or near-misses up to the date of the study.
- There was one incident at the LLC site. It involved a worker trying to tie column rebar at a height of about 8 ft. The worker was attached to the rebar cage to prevent him from falling off, but the cage collapsed, carrying him with it to the ground. The rebar cage was not part of the green features of the building.
- Information was not available about incidents that occurred on the OSUEC project. All of the documents from the project were stored by the general contractor prior to the study.

Since the incidents at the investigated sites were not related to the projects' green features, the researchers attempted to identify additional risks that are associated with the features. To do so, job hazard analysis (JHA) documents, which were prepared by the subcontractors on the projects, were reviewed. Prior to the beginning of any work, major subcontractors submit a detailed project-specific JHA plan. Smaller subcontractors who are not present on the worksite for an extended time are only required to complete a JHA form, which is site-specific, for their weekly work. The researchers were given access to the available JHA reports on the LPSC project. JHA documents are sometimes considered proprietary to the subcontractors, and the general contractors are not always willing to allow third-party access to them. That was the case for two of the case study projects, LLC and HFC. Access to the documents for the OSUEC project was not possible because the documents were already in storage.

Table 1
AP Summary of Risk From LEED Credits

LEED credit	Impact to OSH risk			Reason for change
	Decrease	No change	Increase	
Sustainable sites				
SS 1	--	x	--	--
SS 2	--	x	--	--
SS 4.1	--	x	--	--
SS 4.4	--	x	--	--
SS 5.1	--	--	x	Decrease of available space
SS 5.2	--	x	--	--
SS 7.1	x	--	--	Less handling of hot asphalt
SS 7.2	x	--	--	Different materials; less time on roof
Energy and atmosphere				
EA Prerequisite 1	--	x	--	--
EA 2	--	--	x	Solar panels increase time on roof
EA 3	--	x	--	--
EA 6	--	x	--	--
Materials and resources				
MR 1.1 (2.2)/MR 1.1 (3.0)	--	--	--	n/a
MR 1.2 (2.2)/MR 1.1 (3.0)	--	--	--	n/a
MR 1.3 (2.2)/MR 1.2 (3.0)	--	--	--	n/a
MR 2.1 & MR 2.2 (2.2)/MR 2 (3.0)	--	--	x	Increase material handling
Indoor environmental quality				
IEQ Prerequisite 2	x	--	--	Nonsmoking construction site
IEQ 3.2	--	x	--	--
IEQ 4.1	x	--	--	Reduced VOC
IEQ 4.2	x	--	--	Reduced VOC
IEQ 4.3	x	--	--	Reduced VOC
IEQ 4.4	x	--	--	Reduced VOC
IEQ 8.1	--	--	x	Increase open wall spaces
IEQ 8.2	--	--	x	Increase open wall spaces

Review of the LPSC project's JHA reports showed that the green features are not treated any differently by the subcontractors in the JHAs than nongreen features. In addition, none of the JHA reports indicated any additional or specific OSH risks associated with the green features, and none of the green features were identified as posing greater associated risk than the non-green features on the project.

Assessment of LEED-NC's Effect on OSH Throughout Construction Industry

In LEED-NC versions 2.0, 2.1 and 2.2, six credits specifically address OSH. These credits are all in the IEQ category. The review of LEED credits on 100 randomly selected projects revealed that most of the six credits that explicitly focus on OSH were achieved on 51% to 94% of projects (Table 2). The high percentages are encouraging and suggest widespread benefits to OSH. Achieving the credits that take OSH into account may be facilitated by the increased availability of products that have low VOC compared to previous years, as well as the availability of documentation for these products (Architect, 2010). Whether the decision to attain the credit was based on improving OSH or not, the high percentage of attainment indicates that OSH is being affected positively in some areas.

The extent to which the projects selected and attained those credits identified earlier as increasing risk to OSH ranged significantly in the projects sampled. Credit EA 2: On-Site Renewable Energy was attained by 90% of the projects, while credit MR 2.1: Construction Waste Management was selected and attained by only 13% (Table 3).

Table 2
Projects Attaining LEED Credit for OSH

LEED credit	% of projects attaining credit (±10%)
IEQ 3.1: Construction IAQ Management Plan—During Construction	80%
IEA 3.2: Construction IAQ Management Plan—Before Occupancy	52%
IEQ 4.1: Low-Emitting Materials— Adhesives & Sealants	93%
IEQ 4.2: Low-Emitting Materials—Paints & Coatings	94%
IEQ 4.4: Low-Emitting Materials—Carpet Systems	92%
IEQ 4.4: Low-Emitting Materials—Composite Wood & Agrifiber Products	51%

Note. n = *100*

For the credits identified earlier as decreasing risk to OSH, the sampled projects also attained a high percentage of the credits (Table 4, p. 50). All of the credits were attained by at least 50% of the projects. All of the projects obtained IEQ Prerequisite 2: ETS Control since it is a prerequisite. Of the remaining credits identified as decreasing OSH risk, the IEQ credits that involve the use of low VOC materials were attained by the greatest percentage of projects.

Limitations

Confidence in extending the results of this small study to all construction projects is tempered by several effects resulting from the research methods and constraints. The researchers' assessment of LEED-NC credits depends on their knowledge, experience and biases. This is true as well for the LEED APs on the case study projects. Other researchers and LEED APs may generate differing results. Additionally, the low number of case study projects, local concentration of the projects and limited type of projects inhibits the ability to extend results to all other projects. Increasing the sample size and utilizing a random sample, would provide greater confidence in the results. Also, as noted, the larger margin of error chosen for the assessment of the impact throughout the construction industry increases the range of potential error in the results.

Conclusions

Green design and construction features incorporated into construction projects to achieve LEED certification can affect OSH. For the four construction projects studied, the green features included did not pose any risks foreign to the contractors. This is supported by the engineers and architects involved who indicated that the risks were the same as in any other project that is not LEED certified, and by the JHA reports in which the green features are not mentioned by the subcontractors.

The amount of a particular risk related to a green feature can vary depending on the type of element that is being constructed and how the construction work is performed. As indicated, the risk of falling from height is increased if additional skylights are desired on the roof. A similar risk existed at the LLC project where energy efficiency was introduced in the building by installing solar panels on the roof. Installation of the panels requires workers to work for prolonged periods on the roof, a task that adds to the risk of falling. For both tasks, the contractors used all of the necessary protective measures.

Some green features reduce the amount of risk to which workers are exposed. Such is the case when the contract documents require the use of low VOC products. All of the LEED APs who were interviewed stated that attaining these credits improves workplace quality since the materials that are used do not contain substances that can harm the workers.

Some green features do not pose any additional OSH risk since the features do not require the

workers to perform any task differently in LEED-certified buildings compared to non-LEED buildings. Such tasks include, but are not limited to, the installation of low-flow fixtures, efficient lighting fixtures and the use of environmentally friendly materials in HVAC systems.

A large number of the LEED credits do not affect the workers in any way. Examples are those credits earned by constructing the project in a location with good community connectivity and public transportation. Similarly, other credits are earned by performing more thorough final inspections at a time when no workers are on the site, such as during commissioning. Also, some of the innovation credits implemented on the projects deal exclusively with the completed project and do not affect OSH during construction. One example of this type of credit is the Educational Building credit where a credit is given if the building is used to educate people about green practices.

The impact that LEED is having on construction worker safety and health risk across the country is extensive even though explicit mention of OSH in the LEED credits is minimal. Nearly all of the credits that specifically focus on OSH, or are identified as either increasing or decreasing OSH risk are attained by more than 50% (±10%) of the LEED-certified projects.

Table 3
Projects Attaining LEED Credit as Increasing OSH Risk

LEED credit	% of projects attaining credit (±10%)
SS 5.1: Site Development—Protect or Restore Habitat	24%
EA 2: On-Site Renewable Energy (for the first credit of three)	13%
MR 2.1 (LEED 2.2)/MR 2 (LEED 3.0): Construction Waste Management	90%
MR 2.2 (LEED 2.2)/MR 2 (LEED 3.0): Construction Waste Management	68%
IEQ 8.1: Daylight and Views—Daylight	32%
IEQ 8.2: Daylight and Views—Views	54%

Note. n = *100*

Recommendations

Development of Modified LEED-NC Credits to Address OSH

The literature review, review of the LEED-NC rating system credits and results of the case studies reveal that the presence of formal inclusion of OSH in LEED-NC is limited. This suggests the need for modifications to the credits to improve their effect on OSH. It is possible to increase the presence of OSH by modifying existing credits to include OSH, adding a blanket OSH review requirement for all credits, or adding an OSH section in LEED through the use of Innovation in Design credits. Recommendations for how to modify LEED in each of these ways are described here.

During the review of the LEED-NC 2009 (LEED 3.0) rating system, the researchers identified how potential credits could be modified to incorporate OSH:

•SS 3: Brownfield Redevelopment: On projects where work is performed at designated brownfield sites, include the requirement for developing an OSH assessment plan to protect the construction workers from any hazardous substances present on the site.

•SS 4.1: Alternative Transport—Public Transportation Access: Include a component for OSH by encouraging construction workers to use public transportation to get to the site in order to decrease congestion on the site. This credit includes assurance of safe access of the workers from the public transportation system to the jobsite.

•SS 4.2: Alternative Transportation—Bicycle Storage and Changing Rooms: Include a requirement for bicycle storage facilities during construction projects, encouraging construction workers to improve their health by riding a bike and eliminating potentially crowded worksite parking lots. This credit should only be implemented if the workers are not exposed to increased safety risk due to exposure to vehicle traffic, inclement weather, and lack of illumination when riding a bicycle to/from the jobsite.

•SS 4.3: Alternative Transportation—Low-Emitting and Fuel-Efficient Vehicles: Include a requirement for the use of low-emitting and fuel-efficient vehicles and equipment during construction, leading to a worksite that is less polluted with exhaust fumes.

•SS 6.1 and 6.2: Stormwater Design—Quantity and Quality Control: In these two credits, include a requirement to develop a plan for the reduction of stormwater runoff from the worksite during construction as well as a plan for eliminating or retaining polluting substances that might be carried away with this runoff.

•WE Prerequisite 1: Water Use Reduction: The WE section does not mention the monitoring of the quality of the water during construction and during occupancy. Modify the credit to include monitoring of the quality of the potable water that is used in the building, as well as the quality of the potable water available to the construction crews (Environment and Human Health Inc., 2010). Monitoring water quality at its point of use provides an opportunity to effectively and efficiently ensure and provide a clean source of water on the worksite and also prevent downstream effects. This is especially important on both greenfield and brownfield sites where workers periodically interact with the water distribution system over the course of the construction work. Clean drinking water is essential for worker health.

•MR 1.1 and 1.2: Building Reuse: In the cases where there is building reuse, OSH can be addressed by including a requirement for a plan for the safe maintenance and support of the existing walls and interior nonstructural elements.

•MR 2: Construction Waste Management: For this credit, OSH can be addressed by including a requirement to develop a plan for the safe and healthy management of recycled material produced during construction.

•IEQ Prerequisite 2: ETS Control: Although this prerequisite deals with ETS control for the completed structure, the credit could be modified to

Table 4
Projects Attaining LEED Credits Identified as Decreasing OSH Risk

LEED credit	% of projects attaining credit (±10%)
SS 7.1: Heat Island Effect—Nonroof	52%
SS 7.2: Heat Island Effect—Roof	60%
IEQ Prerequisite 2: Environmental Tobacco Smoke (ETS) Control	100%
IEQ 4.1: Low-Emitting Materials—Adhesives and Sealants	93%
IEQ 4.2L Low-Emitting Materials—Paints & Coatings	94%
IEQ 4.3: Low-Emitting Materials—Carpet Systems	92%
IEQ 4.4: Low-Emitting Materials—Composite Wood & Agrifiber Products	51%

Note. n = *100*

include a requirement for a smoke-free construction site or by adding designated smoking areas for construction crews.

Implementing a few recommended credits may likely require significant effort and cost. For example, using low-emitting and fuel-efficient vehicles (SS 4.3) to reduce the exposure of workers to jobsite pollutants requires alterations to existing vehicles and heavy equipment or purchase of new vehicles and equipment; these changes may be costly. In addition, while utilizing solely electric vehicles and equipment may not be readily feasible when a large amount of usable torque and power, and long electrical charge requirements are needed, switching to electrical power when idling can significantly reduce emissions.

It should be noted that some LEED credits are general in nature and allow implementation of various designs to achieve the same credit. As a result, OSH hazards may be present within a selected design option that are not present in another. A simple review of the LEED credits may not reveal the need for OSH content in the credit in every case. Therefore, in addition to including OSH management content within specific credits, an overall requirement could be added that requires consideration of OSH within all credits. That is, to achieve each credit, OSH must be shown to have been a decision criterion when selecting the design or construction feature and that recognized OSH hazards have been mitigated.

Through the use of Innovation credits, LEED 3.0 provides an option for obtaining credits from other sustainable features that are not explicitly included in the rating system. Another way to incorporate additional OSH is by including a pilot Innovation credit on OSH. The Innovation credit would include additional considerations for OSH of the construction workers, as well as provide an incentive for the owners, designers, contractors and workers to work together for a safe and healthy work environment. After piloting the credit on projects, the credit could then be expanded into a section of its own in future versions of LEED. Following is a draft of a proposed pilot credit by Paul Muller of Muller Architects Inc., and modified based on the results of this research study (Muller, 2010).

Pilot Credit: Enhanced Construction Safety Plan (1-3 points)

Intent: The intent of the credit is to maximize the safety and health of people on the construction site. This aim is achieved through utilizing innovative approaches and techniques that increase safety throughout the entire process of design and construction, and by encouraging the use of safe practices and participation in safety thinking by all project participants.

Prerequisites: To be considered for this pilot credit, projects must satisfy the following LEED credit requirements. Exception will only be given when the following credits are not applicable to the project.

- IEQ 3.1: Construction Indoor Air Quality Management Plan—During Construction;
- IEQ 3.2: Construction Indoor Air Quality Management Plan—Before Occupancy
- IEQ 4.1: Low-Emitting Materials—Adhesives and Sealants;
- IEQ 4.2: Low-Emitting Materials—Paints and Coatings;
- IEQ 4.3: Low-Emitting Materials—Flooring Systems;
- IEQ 4.4: Low-Emitting Materials—Composite Wood and Agrifiber Products.

Requirements: In addition to the prerequisites, at a minimum, ensure that the project employs cross-discipline design and decision making, beginning in the programming and predesign phase, and includes the following activities:

I) Preliminary safety goals. Before schematic design, conduct a preliminary safety meeting of at least the four key project team members (as described below) including the owner or owner's representative. During the meeting:

A) Create a safety and health action plan that, at a minimum, includes the following:

1) The safety targets (desired outcomes) for the project; and

2) The creation of a safety and health action team that will monitor all safety and health aspects for the project. The action team should include representatives from major parties involved, such as owner, designer, contractor and major subcontractors. Since contractors are not always known during schematic design, members can be added as the major parties join the project.

II) Design for safety plan. This plan should address how the project team will review and design the project for the safety of the construction workers, maintenance staff and facility operators. The design team must incorporate safety aspects into its design and consult with contractors whenever possible. Design elements in the proposed construction must be designed for safety and health

for everyone involved during construction, operation and maintenance. Priority shall be given to designing out safety and health hazards wherever practicable.

III) Prepare a construction safety plan. This should significantly exceed OSHA Safety and Health Standards for Construction (29 CFR 1926). Exceed OSHA 30-hour training and certification by a verifiable amount. Review federal guidelines such as EM-385.1.1 for additional safety strategies. The safety plan also should include sections, where applicable, for the following construction activities:

A) If construction involves brownfield redevelopment, according to Credit SS 3, potential risks to worker safety and health must be outlined in the safety plan along with the necessary actions to handle any brownfield redevelopment risks.

B) If construction involves the reuse of existing walls, floors, roofs and interior nonstructural elements as described in Credits MR 1.1 and MR 1.2, the safety plan must address any potential risks to workers and list the actions to counteract the risks.

C) The safety plan must include instructions for the safe handling of construction waste material as described in Credit MR 2.

D) The safety plan must include instructions for the safe reuse of materials that are salvaged from the construction site as described in Credit MR 3.

E) The safety plan must prescribe a smoke-free construction site.

IV) Training. Conduct the OSHA 10-hour construction outreach training course, and make it mandatory for all workers and managers involved in the project as well as members of the design team.

V) Monitoring. The safety and health action team shall monitor the implementation of both the design for safety plan and the construction safety plan, and report status to all participants of the project on a regular basis. Modifications to the plans shall be made to mitigate any identified deficiencies and improve safety and health performance.

VI) Safety meetings. Conduct safety meetings on a regular schedule during all phases of design and construction to review current and upcoming safety issues.

VII) Final report. At the conclusion of construction, prepare a final report that presents the actions taken to improve worker safety and health and the level of safety and health performance attained on the project.

Point allocation: The point distribution assigned to each of these elements shall be as follows:

I) 1 point. For a new construction project to be eligible for one point for this pilot credit, it must at a minimum:

A) Satisfy all of the prerequisites and requirements; and

B) Improve by 25% the safety performance on the project in terms of incidence rates for fatal and nonfatal injuries compared to projects of the same type as published by Bureau of Labor Statistics (BLS) (25% lower than BLS value).

II) 2 points. For a new construction project to be eligible for two points for this pilot credit, it must, at a minimum:

A) meet all requirements necessary to attain the first point;

B) improve by 50% the safety performance on the project in terms of incidence rates for fatal and nonfatal injuries compared to projects of the same type as published by BLS (50% lower than BLS value);

C) set up a plan for monitoring and evaluating potable water quality for construction crews and the completed project that meets and exceeds acceptable local environmental standards (Environment and Human Health Inc., 2010);

D) provide significant reduction in the amounts of formaldehyde, particulates, pesticides, bisphenol-A (BPA), phthalates, perfluorooctanoic acid (PFOA) and volatile organic compounds (VOCs) used in the construction materials for the proposed construction (Environment and Human Health Inc., 2010).

III) 3 points. For a new construction project to be eligible for three points for this pilot credit, it must, at a minimum:

A) meet all requirements necessary to attain the first and second points;

B) improve by 75% the safety performance on the project in terms of incidence rates for fatal and nonfatal injuries compared to projects of the same type as published by BLS (75% lower than BLS value);

C) provide temporary housing for workers having to commute a distance of more than 90 miles from the construction site.

Potential technologies and strategies: The following are potential technologies and strategies that could be employed to obtain this innovation credit (Muller, 2009):

1) Reinforce corporate/institutional commitments to OSH.

2) Use cross-discipline design, decision making and charrettes. Use goal-setting workshops and build a team approach to project safety.

3) Prepare checklists for strategies prior to beginning the design process; refer to the checklist at milestones during the design process.

4) Engage owner, staff, designers, contractors, user group, and community groups, educating them on the benefits of PTD and bringing them into the safety planning process at key points.

5) Participate in peer-to-peer information exchange and problem solving.

6) Consider performance-based incentives in professional contracts that reward achievement of a safe design and a safe work environment. Incentives may be based on comparisons to benchmarks of existing facility design and facility construction.

Some of these activities and requirements indicated may already be part of a contractor's safety

efforts. For example, pretask planning and conducting JHAs commonly involve contractors identifying possible risks and controls. Similarly, many contractors already conduct regular safety meetings, and may provide OSHA 10-hour training for all of their employees. Such companies are already safety conscious and most likely have safe jobsites. The additional impacts on the operations of these companies may be minimal.

These additional measures do present extra costs. Providing OSHA 10-hour training for employees, for example, includes the cost of the training plus the cost of the time off to attend training. Initial costs to achieve the credits also are expected for other items such as additional staff to monitor the site for safety hazards, architect/engineer time to design the project for safety, and time to develop and submit a final safety report.

It is well known, however, that additional investment in OSH pays off over time in fewer injuries, lower insurance premiums, and higher morale and productivity. Additionally with the project owner involved in promoting OSH through LEED certification, the owner will be willing to support the additional costs. The monetary costs of attaining the credits can be passed on to the owner through the bid process regardless of the size of the construction firm.

Future Research

The present study was conducted using small study samples. A more in-depth investigation is necessary to provide complete understanding of the effects of LEED-certified buildings and their green features on OSH. The researchers suggest that an investigation be conducted of the effects of these features on a longer time scale to assess their performance on the personnel associated with the maintenance of the facilities. Also, since the various credits can be obtained in various ways, the researchers suggest a broader study that investigates all of the methods in which projects obtain these credits and how each affects OSH. **PS**

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