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Using failure mode and effects analysis to evaluate barriers to the greening of existing buildings using the Leadership in Energy and Environmental Design rating system

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ABSTRACT

Despite a recent increase in the greening of existing buildings, the literature continues to focus on investigating barriers to the greening of new buildings. The goal of this research was to develop a method using failure mode and effects analysis to investigate the barriers to the greening of existing buildings using the Leadership in Energy and Environmental Design version 4 for Building Operations and Maintenance: Existing Buildings rating system. Its specific objectives included using this method to 1) investigate potential failure modes when certifying existing buildings using this rating system, as well as their causes and effects, 2) rank failure modes, effects and causes in order of priority and 3) identify opportunities and lessons learned from implementing this method. The research involved bringing together a focus group of five local experts who were familiar with the rating system for a one-day workshop. The experts, along with the research team, were tasked with identifying these potential failure modes along with their causes, effects and detection controls and with rating the probability of occurrence of the failure modes, the severity of the failure effects and the ease of detection of the failure controls. The analysis of the workshop data showed that over half of the identified failure causes were technical in nature, with financial causes and organizational causes representing 14% and 11% of all failure causes, respectively. The analysis also showed the intricate relationship between technical, financial, organizational, social and environmental factors; therefore, these different factors need to be integrated and interlinked, rather than compartmentalized and separated. This research provided a new comprehensive method based on the use of failure mode and effects analysis to evaluate the risks to the greening of existing buildings using the Leadership in Energy and Environmental Design rating system. Workshop participants found failure mode and effects analysis to be an excellent method for identifying, evaluating and ranking green building certification risks because it helped to foster interdisciplinary collaboration between participants from various disciplines, as well as between researchers and industry stakeholders. Nevertheless, there is a need for future applications of the method to limit the scope of the analysis to specific categories or credits of the rating system. This narrow scope would facilitate the analysis of the workshop data and enable a more in-depth and comprehensive analysis of all risks and risk types, including ones that traditionally tend to be ignored, such as organizational and social risks.

1. Introduction

Despite increasing evidence in the literature regarding how green buildings may be outperforming traditional buildings with respect to water and energy consumption and indoor environmental quality (e.g., Liang et al., 2014; Hirning et al., 2013; Collinge et al., 2013), the literature provides less evidence about the effectiveness of green building rating systems (Hammad et al., 2014; Wang et al., 2013), despite the popularity of a number of these systems, such as the Leadership in Energy and Environmental Design (LEED) rating system. Moreover, despite a recent increase in the greening of existing buildings, the industry continues to focus on the design and construction of new buildings. This trend has been shown in the literature by a focus on new buildings as

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opposed to existing ones, prompting the need for research that addresses existing buildings and, in particular, barriers to their greening.

The goal of this research was to develop and validate a method using failure mode and effects analysis (FMEA) to investigate barriers to the greening of existing buildings using the LEED version 4 for Building Operations and Maintenance: Existing Buildings (O + M: EB) rating system. Specific objectives included using FMEA to 1) investigate potential failure modes when certifying existing buildings using LEED O + M: EB as well as their causes and effects, 2) rank failure modes, effects and causes in order of priority and 3) identify opportunities and lessons learned to improve the implementation of this method. The research aimed to evaluate the use of FMEA on existing buildings covered by the LEED O + M: EB rating system and thus addressed all building types except for schools, retail, data centers, warehouses, distribution centers and hospitals. This study was not limited to one type of barrier and aimed to provide researchers and industry stakeholders with a tool to address challenges associated with the greening of existing buildings.

2. Literature review

This section includes a review of the literature regarding the barriers to green building and an overview of the LEED O + M: EB rating system. This section also includes a review of the most common risk analysis methods used in the literature, focusing on FMEA and its use in construction research.

2.1. Barriers to green building

A review of the literature revealed a focus on investigating barriers to the greening of new buildings as opposed to existing buildings (Afshari et al., 2013). Very few papers have been published on existing buildings (e.g., Edwards and Kumphai, 2012). Barriers to greening existing buildings comprise financial, technical, social, environmental and organizational barriers (Edwards and Kumphai, 2012; Zhang et al., 2012 and Ahn et al., 2013). Financial barriers include the cost premium of green projects, their long payback period and limited budgets (Ahn et al., 2013; Zhang et al., 2011). Technical barriers include stricter building codes and green design guidelines; the lack of expertise, training and education; and inadequate materials, equipment and technologies (Bandyopadhyay, 2013; Tollin, 2011 and Ahn et al., 2013). Social barriers comprise the tendency to maintain conventional attitudes and practices (Ahn et al., 2013). Organizational barriers include the lack of strategic, long-term planning as well as the lack of commitment and involvement by green building owners, managers and tenants in the green certification process (Edwards and Kumphai, 2012; Zhang et al., 2012; Lozano, 2009).

A review of the literature also showed a traditional focus on investigating hard barriers such as technical and environmental barriers as opposed to soft barriers such as organizational barriers (Lozano, 2012, 2013). There is even less focus on individual and group barriers despite the importance of these barriers in achieving corporate sustainability, which would help companies to overcome resistance to change, tackle sustainability in a more holistic manner and address traditional technical and environmental barriers. Recent research (e.g., Doppelt, 2003) aims to address this gap by investigating these organizational barriers and strategies to overcome them.

The review also showed that literature on the topic lacked comprehensive methods in the form of frameworks, models or processes for assessing barriers to the greening of existing buildings (Chowdhury et al., 2015). Very few studies (e.g., Edwards and Kumphai, 2012; Lozano, 2015) developed such methods for existing buildings and organizations. Most studies (e.g., Chowdhury et al., 2015; Mecca and Masera, 1999) developed these methods for new buildings.

2.2. Leadership in Energy and Environmental Design rating system

The LEED version 4 for Building Operations and Maintenance: Existing Buildings (O + M: EB) rating system is one of six adaptations that currently exist for LEED version 4 for Building Operations and Maintenance (LEED O + M). The system is administered by the Canada Green Building Council (CaGBC) to rate the sustainability of different types of existing buildings (CaGBC, 2015a). LEED O + M uses a set of 39 credits worth a total 110 points divided into eight categories, each comprising a set of credits worth a specific number of LEED points. The CaGBC awards projects one of four levels of certification, Certified, Silver, Gold or Platinum, depending on the total number of points earned (CaGBC, 2015a).

The Location and Transportation (LT) category focuses on a building's location with respect to the surrounding community, promoting aspects such as compact development, alternative transportation and connection to local amenities (USGBC, 2015). The Sustainable Sites (SS) category encourages the protection of sensitive ecosystems, local habitats, open space and water bodies. SS promotes development methods that reduce construction pollution, heat island effects, light pollution and rainwater runoff. The Water Efficiency (WE) category aims to reduce indoor water use through the use of water-efficient fixtures, appliances and processes. WE also aims to reduce outdoor water use and promote the use of non-potable, alternative water sources (e.g., rainwater harvesting). The Energy and Atmosphere (EA) category focuses on reducing energy use through strategies such as installing energy meters, participating in demand response programs, using renewable energy sources and effective building commissioning. The Materials and Resources (MR) category aims to reduce the environmental harm associated with using, purchasing and disposing of building materials for existing buildings, reducing and recycling the solid waste generated in the process. The Indoor Environmental Quality (EQ) category rewards strategies aimed at minimizing environmental tobacco smoke exposure, reducing contaminants and improving indoor air quality. EQ also focuses on promoting thermal comfort, high-quality lighting and occupant comfort. The Innovation (IN) category promotes innovative sustainable building practices and strategies, while the Regional Priority (RP) category encourages projects to focus on local environmental priorities related to their geographical area or country.

2.3. Risk analysis methods

A number of definitions have been proposed in the literature for what constitutes “risk.” Among the definitions proposed by Aven (2012), this research describes risk as “the probability and severity of a consequence” and the “uncertainty and severity of the consequence stemming from uncertainty” (Aven, 2012).

Groso et al. (2012) reviewed over a hundred risk analysis methods. Some methods are applicable to all industries (e.g., FMEA and preliminary hazard analysis), whereas other methods are more industry specific (e.g., event tree analysis). Some methods are more qualitative in nature (e.g., preliminary hazard analysis), relying on the judgement and knowledge of experts, while other methods are more quantitative (e.g., FMEA), using metrics and weights to avoid the bias of research investigators.

The preliminary hazard analysis method aims to identify hazards, assess the severity of accidents involving those hazards and