

Green Building Construction Practices: Review of Environmental Management from the Contractor Perspective in the Canadian Industry

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Abstract:

Green building is a practice applied to the whole life cycle of a building, which means its environmental performance is not only defined by design, but also by the management processes in the construction, operation, and maintenance of a building. Over the past 10 years, research in green buildings has been increasing, mostly focusing on the design and energy efficiency. Contractors now represent a critical role in sustainability, but they have received less support and attention than the design community. This paper focuses on three main areas: practices on site, project management, and organizational support. While contractors in Canada are focusing on the implementation of green practices mainly established by LEED; a main problem is that the concept of "green" remains unclear and ambiguous in on-site practices. This research started with the identification of green building construction practices available to contractors by reviewing and comparing green building standards and literature review. Next, this research considered the management perspective by conducting semi-structured interviews in four construction organizations in order to document how LEED is integrated into project management and what issues companies are facing in the implementation of green construction practices. In addition, this research identified best practices in how these companies are supporting the reduction of environmental impacts during the construction phase. Overall, this paper highlights the different green construction practices that Canadian contractors can apply to advance their environmental sustainability, along with four case studies to document LEED construction management and an overview of the organizational tools used by companies for their environmental management.

Keywords:

sustainable construction management, sustainable practices, LEED, environmental management, contractor role.

1. Introduction

Literature such as journal papers, conference papers, reports, whitepapers, and books are replete with definitions, frameworks, and models to define and implement sustainability. Most of them start addressing sustainability from one of the most popular definitions for sustainable development mentioned in 1987 by the U.N World Commission on Environment and Development (WCED) in the Brundtland Report. According to the definition established, sustainable development refers to "development that meets the needs of the present without compromising the ability of future generations to meet their own needs". (WCED, 1987).

Sustainability is also generally described in terms of the triple bottom line. The triple bottom line goal was first established by John Elkington in his 1998 book, "Cannibals with Forks: the Triple Bottom Line of 21st Century Business" (USGBC, 2014), incorporating social, environment and economic perspective.

The definition of sustainable development and the triple bottom line seems to be applicable to every field from global development policies to the building industry. The building industry has a significant effect on the environment and human health as they consume more than one-half of the world's physical resources and account for 30% to 40% of the world's energy use.

(CSC, 2011). In this context, sustainability means creating places environmentally responsible, healthful and profitable (USGBC, 2014) and in order to achieve this, the building industry has been shifting the traditional practices to green practices.

Green building has been defined by many organizations. The US EPA defines it as the "practice of creating structures and using processes that are environmentally responsible and resource-efficient throughout a building's life-cycle from siting to design, construction, operation, maintenance, renovation and deconstruction" (US EPA, 2016). Essentially, green building is defined as the practice, method or even process of continual improvement (USGBC, 2014) applied to the whole life cycle of a building to increase efficiency and reduce its impacts, but not as the end product.

Green building growth in Canada has been promoted by building owners, institutional investors, corporate sustainability policies and building code/by-law requirements; but voluntary adoption has played a major role in the increase of green buildings. As of 2015, LEED buildings have eliminated 1,261,016 CO₂e tons of GHG emissions, diverted over 1.5 million tonnes of waste from landfill, and saved 12.8 billion liters of water per year in Canada (CAGBC, 2017).

Green building practices have evolved quickly, challenging the construction industry for a quick adaptation in their business practices and field operations (Tan et al., 2011). Contractors are participating and representing a crucial role in the success of green buildings as the implementation and documentation of some credits depend exclusively on them. (Rosenberg et al., 2003). For this reason, contractor's are taking not just the responsibility in achieving sustainability requirements but also developing strategies to streamline the processes.

2. Research Objectives

This paper has three main objectives:

1. To identify the green building practices established in current green building standards that particularly impact the construction phase.
2. To document the integration of LEED construction practices in the project management areas established by the Project Management Institute.
3. To document the organizational approach from contractors for the implementation of green building construction practices.

To achieve the first objective, literature review and a comparison of five green building rating systems was conducted in order to identify green construction practices that can be implemented by contractors.

For the second and third objective, semi-structured interviews to four construction organizations were conducted. The main focus was on LEED management in green buildings, mostly considering pre-construction and construction phases, which fall under the project management team. Information about organizational support and tools for the management of green building site practices was also gathered through the interviews.

3. Environmental Management Framework

This research follows a framework method for the management of qualitative data. The framework used is shown in Fig 1.



Fig 1: Environmental Management Framework

The reason to use this framework is that each layer is fundamental to achieve the best outcome of environmental sustainability in projects. The technical aspects will define environmental practices to be

managed in the construction phase. However, the nontechnical aspect is equally important for successful implementation of green building. Management is believed to be the factor that most often determines the success or failure of a project (Imada 2002), (ISO, 2013), so this was included in the next two layers. Project management is "the application of the application of knowledge, skills, tools, and techniques to project activities to meet the project requirements" (PMI, 2013). A study suggested that project management factors such as human-resources oriented factors, technical and innovation-oriented factors, support from designers and senior management, project manager's competence, and coordination of designers and contractors are essential for the success of green building projects (Yuan Li et al., 2011).

The third layer arises because the construction industry is a project-based organization, creating "temporary systems" for carrying out their work. Project management activities should be aligned with top-level business direction and organizational strategy (PMI, 2013). Organizational strategy also relates to how environmental performance can be managed and controlled, including standards, organization policy and implementation systems (Poser et al., 2012). According to ISO 14031, management performance and indicators related to policies, people, planning, activities, practices, documentation, and procedures at all levels of the organization, including actions related to the environmental aspects will directly affect the performance in the organization's operations, influencing the environmental performance.

4. Green Construction Practices

LEED is a performance-based rating system that provides a framework for design, construction, and operation of buildings. LEED 2009, which is the version used on the case studies evaluates performance in seven key areas (Yellamraju, 2010) (CAGBC, 2010):

- Sustainable Sites: selection, design, and management of project sites.
- Water Efficiency: water reduction strategies.
- Energy and Atmosphere: energy efficiency of buildings and energy consumption.
- Materials and Resources: waste reduction and selection of sustainable materials.
- Indoor Environmental Quality: the improvement of the overall indoor air quality of buildings.
- Innovation in Design: innovative strategies not addressed by the other credit areas or exemplary performance, which means going beyond the normal requirements for LEED credits.
- Regional Priority: credits that have been identified to be important priorities for a particular region.

In addition to the achievable credits, there are certain prerequisites under each category that the project must meet. The number of points will determine the level of

certification. The levels that can be achieved are as follows:

- Certified: 40-49 points
- Silver: 50-59 points
- Gold: 60-79 points
- Platinum: 80 points and above

At present, sustainability in the construction industry often means applying LEED. LEED Canada NC-1.0 was introduced in 2004 and, since then, the number of certified building has grown rapidly from 31 certified buildings in 2005 to 2,576 buildings in 2015 (CAGBC, 2016). The Government of Canada established that LEED Canada has transformed the way that built environments are designed, constructed and operated—not only buildings but also homes, neighborhoods, and communities (Government of Canada, 2015). LEED will continue to be used to promote sustainability as building operators and corporate executives considered it to be a key way to communicate sustainability to stakeholders and to support corporate sustainability efforts (Long, 2015).

In a recent life cycle assessment study made for a 4000 m² office building, the construction phase represented between approximately 3% to 9% of the life cycle impact of the building (Delem et al., 2013). However, while LEED is widely implemented, it offers more specific recommendations in the planning and design phases of projects (O'Connor et al., 2015). This is problematic, as the environmental performance of a building is not only defined by the design features of a building, but also by the management processes for the construction, operation, and maintenance of a building (ISO, 2010).

Certain approaches and aspects of green buildings—such as energy efficiency—are becoming more standardized, but there is still a lack of common understanding in terms of site management (CSC, 2011). Also, research has focused on design and energy efficiency, while only 4% of the research relates to on-site practices (as reported in a study of the state of knowledge of green buildings, evaluating 218 papers and published in the International Journal of Construction Engineering and Management) (Owens by-Conte & Yepes, 2012).

LEED 2009 practices that most impact the contractor are site disturbance, material tracking, waste management and indoor air quality. (Syal et al., 2011)(Mago, 2007) Table 1 was developed to show a complete list of environmental technical and management practices that contractor can implement during construction. Practices considered were taken from the green building rating systems LEED 2009, LEED v4, Green Globes, BREEAM, REAP and two journal papers (O'Connor et al., 2016) (Zou & Sungwoo, 2013).

Table 1: Environmental Building Construction Practices

Category	Subcategory
Site Disturbance	Soil erosion
	Waterway sedimentation
	Airbone dust generation
	Limit site disturbances
	Site vegetation protection and restoration
	Tree preservation plan
	Staging and Construction Plan
Materials	Materials Reuse
	Recycled Content
	Regional Materials
	Rapidly Renewable Materials
	Certified Wood
	EPD
	Sourcing of Raw Materials
Material Ingredients	
Waste Management	Construction Waste Management Plan
	Waste Monitoring
	Total waste final report
	Minimum values for % of Waste Diversion
	Minimum # of material streams diverted
Indoor Air Quality	Source Reduction Strategies
	Adhesives and Sealants
	Paints and Coating
	Flooring Systems
	Wood Products
	Insulation
	Furniture
	IAQ Plan
	HVAC Protection
	Pathway interruption
	Housekeeping
	Scheduling
	Moisture damage to materials
	Policy for non-smoking
Air-handlers filtration media	
Flush-out	
IAQ testing report	
Equipment Related Practices	CxA authority
	Commissioning systems
	Commissioning final report
	Equipment energy efficiency
	Selection and replacement of equipment
	Reduction in idling of equipment
	Truck management plan
	Wheel wash /Tire-cleaning
	Clean Diesel Practices
Inspection and maintenance of equipment	
Construction Site	Energy Use Reduction
	Energy Monitoring
	Water Use Reduction
	Water Monitoring

	Monitor Transport Data Materials	
	Monitor Transport Data Waste	
	Assessment under local legislation	
	Noise Management Plan	
	Noise - Mitigation measures	
	On-site monitoring measures	
	Assessment under local legislation	
	Equipment selection	
	On-site reduction measures	
	On-site monitoring measures	
	Light Pollution	
	Sustainable Temporary Facilities	
	Management Related Practices	Green Building Professional
		Green Building Professional Specific to Construction
Environmental Management Tools		
Environmental Policy		
Regulatory Compliance and Training		
Environmental Risk Assessment		
Environmental Risk Management Strategies		
Environmental Management Roles, Responsibilities and Reporting Structure		
Site and Work Instructions for site personnel		
Environmental Inspection Checklists		
Records of Compliance		
Train Workers for Emergency Response		

The most frequently implemented green site practices by Canadian contractors are reuse of buildings materials, recycling, and site protection, which are already established by LEED. (CSC, 2011) On-site energy conservation was the next most prevalent, which can increase profit margins, improve resource efficiency, and reduce environmental impacts (Gottsche et al., 2016). Relevant practices that can be applied on-site, not covered by LEED, concluded from Table 1 are:

- Monitoring Energy Consumption: related to equipment and site.
- Monitoring Water Consumption: related to equipment and site.
- Monitoring of Transportation Data: not only from materials, but also from the evacuation of soils and waste, which means monitoring the truck from the construction gate to waste disposal.
- Equipment Related Practices: reduction of idle times, clean diesel practices, selection and maintenance of equipment, tire-cleaning and a truck management.
- Environmental Management System: includes environmental policy, environmental inspection checklists, records of compliance, management strategies, reporting structure, and more.

5. Case Study Information

Semi-structured interviews were conducted in four construction organizations. The information about the companies is shown in Table 2. The person interviewed was either project manager or project coordinator who had knowledge of environmental practices implemented on site.

Table 2: Case Study Information

1	<p>Company:</p> <ul style="list-style-type: none"> •General contractor •International company with a Canadian subsidiary •Operate in all provinces in Canada -Offices in Toronto, Ontario and BC <p>Project:</p> <ul style="list-style-type: none"> •Design-build project •School project under LEED 2009 •LEED Gold •Upgrade project •Located BC
2	<p>Company:</p> <ul style="list-style-type: none"> •General contractor & construction manager •Operates in BC •Focus is on multi-unit residential, commercial, light industrial, recreational, institutional and municipal construction projects •Services range from development management, general contracting, construction management, and other project delivery methods. <p>Project:</p> <p>No specific project</p>
3	<p>Company:</p> <ul style="list-style-type: none"> •International company •Operates in all provinces in Canada -Focus on large commercial, institutional and civil construction projects <p>Project:</p> <ul style="list-style-type: none"> •Construction Management •New construction and renovation project under LEED 2009 •LEED Silver •Located in BC
4	<p>Company:</p> <ul style="list-style-type: none"> •Services range from preconstruction, construction, virtual construction and work with several project delivery methods •Operate in BC and Alberta •Focus on commercial, residential and institutional buildings <p>Project:</p> <ul style="list-style-type: none"> •Design –bid-build •Residential building with community centre, park and plaza -LEED 2009 Gold -Located in BC

6. Results and discussions

a. Project Management Perspective

Management practices must be modified in order to incorporate sustainable practices into design and construction processes (Syal et al., 2011). There are a number of project management frameworks in existence for a variety of purposes. The ones chosen as foundations for this paper were based on the book "LEED-New Project Management" (Yellamraju, 2010) and the fifth edition of the Project Management Body of Knowledge (PMI, 2013).

The Guide to the Project Management Body of Knowledge, known as the PMBOK Guide, was developed by the Project Management Institute to provide guidelines for managing individual projects, define project management related concepts, and describe project life cycle and related processes (PMI, 2013). The PMBOK Guide describes 47 project management processes within 5 project management process groups and 10 knowledge areas. This paper used the knowledge areas, which are mainly defined as "set of concepts, terms, and activities that make up a professional field or area of specialization" to categorize the information obtained in the case studies. The knowledge areas are integration, scope, time, cost, quality, human resources, communications, risk, procurement, and stakeholder management.

The companies were asked how LEED is integrated in project management. Three of the companies mentioned that scope and cost management were the most impacted by LEED. The results obtained are summarized in Table 3.

Table 3: LEED integration in Project Management

Integration	<ul style="list-style-type: none"> •More Diligency with Change Orders •More Design Reviews
Scope	<ul style="list-style-type: none"> •Overall Project Administration •LEED Plans •LEED Calculations •LEED Implementation Documentation •Response for GBCI after months
Time	<ul style="list-style-type: none"> •Meetings integration with master schedule •Inspections Integration with master schedule •Document submission deadlines •Follow up time for certification •Scheduling of activities
Cost	<ul style="list-style-type: none"> •Total Project Cost •Cost Estimations Presentation •Administrative costs: Paperwork + LEED Coordinator
Quality	<ul style="list-style-type: none"> •Additional inspections on site •Quality of trades •LEED review progress

Human Resources	<ul style="list-style-type: none"> •Additional training for Subcontractors •Additional team member •Additional team responsibilities •Green knowledge/ experience
Communication	<ul style="list-style-type: none"> •Client reporting •LEED Consultant •Weekly /monthly meetings •Pre-kick off meeting
Risk	<ul style="list-style-type: none"> •Penalty for compliance •Risk considerations for delays for doc. •Risk considerations for delays for measures •Emergency response strategies
Procurement	<ul style="list-style-type: none"> •Specs in Contracts and Agreements •Availability for materials
Stakeholder	<ul style="list-style-type: none"> •More client engagement to the project

Participants were also asked to provide common issues concerning green construction practices implementation, including: material tracking, waste management, site disturbance and indoor air quality. The severity and impact of each issue were also asked about, and the results were classified and presented in Table 4. The impact and severity considered are shown in Figure 2, where HS stands for high severity, HO for high occurrence, LS for low occurrence and LO for low occurrence. The table also presents several abbreviations to better display the information: W stands for waste management, SD for site disturbance, IAQ for indoor air quality and M for materials. The number displayed in brackets represents the number of the corresponding case study that specifically emphasized that issue.

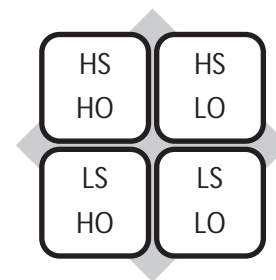


Figure 2: Impact and Severity Matrix

Table 4: Practices Issues in Project Management Areas

Integration	M: Design Change [HS,HO][2]
Scope	SD: Site specific details not considered early in the process [HS,LO] W: Wrong estimates of waste [HS,LO][1] W: Poor diversion strategies [HS,LO][1]
Time	W: Poor construction scheduling [LS,HO] IAQ: Occupancy required before flush-out [LS,HO] W: Site Layout since the beginning of project [HS,LO] [3]
Quality	SD: LEED Consultant experience about constructability issues [LS,HO] W: Collaboration of Site Workers [LS,HO][2] W: Knowledge of Measures [HS,LO] IAQ: Trades knowledge of measures [LS,LO]
Human Resources	SD: Poor record keeping procedures [HS,LO] W: Poor record keeping procedures [HO,LO][2]
Risk	M: Delays for incomplete documentation [HS,LO] SD: Delays for not measures in place [HS,LO]
Procurement	M: Wrong spec. For materials in contract doc. [HS,LO] W: Wrong documentation from subs [HO,LO][2, 1]

b. Organizational Perspective

One of the main reasons for which contractors are increasing their level of green activity is to improve their branding/public relations (CAGBC, 2014); therefore, they will try to incorporate green construction strategies to differentiate their businesses from others. These strategies are supporting the current green building standards.

McGraw-Hill conducted a study demonstrating that only 9% of construction companies actually transformed sustainability into their organization and daily practices (McGraw Hill Construction, 2012). Therefore, it is important to develop organizational transformation strategies that allow companies to successfully adopt and implement sustainability (Kang Hee, Ahn, Jeon, & Suh, 2014).

This research is intended to identify best practices relating to the organization perspective. Best practice research relies on the idea of communicating and transferring practices that seem to work well somewhere else. Best practice research—also referred to as "good practice" and "smart practice"—has been described as being practical and useful (Vesely, 2011).

Participants were asked to describe how their companies support green building construction practices implementation and the results are summarized in Table 5.

Table 5: Organization Tools for Green Building Practices Implementation

Company	Organizational Support
1	<p>Guidance for On-Site Practices</p> <ul style="list-style-type: none"> • Specific sustainability model • In-house <i>Environmental Label</i>: Based on ISO + Environmental Stds (BREEAM + LEED) from Parent Organization • CANADA: LEED Protocols • Integrated Health and Safety Policy <p>Measurement Framework</p> <ul style="list-style-type: none"> • Environmental Inspection Report (Performance Indicators) • Sustainability Reporting Available <p>Initiatives</p> <ul style="list-style-type: none"> • Promote solution for reducing carbon footprint • LCA for promotion of new construction methods and low carbon materials • Calculate carbon footprint
2	<p>Guidance for On-Site Practices</p> <ul style="list-style-type: none"> • Operations Manual /Guidelines • LEED Protocols <p>Measurement Framework</p> <ul style="list-style-type: none"> • Inspection report (Performance Indicators related to LEED) • No Sustainability Reporting Available <p>Initiatives</p> <ul style="list-style-type: none"> • Site-specific green building initiatives • In house consultants (commissioning) • Provide in house administrative requirements for certifications
3	<p>Guidance for On-Site Practices</p> <ul style="list-style-type: none"> • Specific sustainability model • EMS: based on ISO • Integrated Health + Safety Policy • LEED Protocols <p>Measurement Framework</p> <ul style="list-style-type: none"> • Environmental Inspection Report (Performance Indicators) • No Sustainability Reporting Available <p>Initiatives</p> <ul style="list-style-type: none"> • Office space guidelines • Company evaluation /reporting

7. Conclusions and outlook

Canada's green building industry has grown quickly, but more training and support is needed to help the

construction industry to understand, design and build buildings that achieve high environmental, economic and social aspirations (CAGBC, 2016). As a general contribution, this research provides a review of green building construction practices and environmental management in the Canadian industry from the contractor's perspective.

This research can be used as a guideline for contractors that are trying to improve or incorporate more green construction practices in their operations. Section 4 details a number of practices beyond LEED that will help reduce the environmental impact of the construction activities. These practices were determined by reviewing different green building standards, complemented with the review of several journal papers.

In addition, this paper reviewed the project management perspective by conducting semi-structured interviews in four construction organizations. This contribution is to show how LEED is integrated into construction project management and by identify the issues related to material tracking, waste management, indoor air quality and site disturbance facing Canadian contractors.

Finally, this research determined several best practices in organization tools that can support the implementation and management of green construction practices.

The three main conclusion from this paper are:

1. Contractors are looking for guidance and resources for conducting sustainable construction activities to improve their sustainability performance. The practices from LEED 2009 that most impact the contractor are:

- Site disturbance
- Material Tracking
- Waste Management
- Indoor Air Quality

However, there are other construction green practices that contractors can apply in their projects. Contractors can support environmental sustainability by monitoring energy and water consumption on site, in addition to just reduction techniques. Additional practices can be monitoring of transportation data, equipment related practices and management techniques such as an EMS (Environmental Management System).

2. LEED is highly integrated into project management practices and—even though it is not considered as an "impact"—the companies still identified that LEED mainly affects the PM areas of scope and cost management. Other issues related to green practices are related to materials coordination, waste management, indoor air quality and site disturbance.

The most serious issue was related to human resources management. A lack of collaboration and knowledge of subcontractors and the workforce are reported to be the main cause of issues in material coordination, indoor air quality measures, site

disturbance inspections and waste management procedures. General training on green buildings for subcontractors and field supervisors is considered as the most effective strategies to mitigate these problems.

3. The best practices identified were as follows:

1. Follow LEED guidelines on projects, even if the formal certification process is not pursued.
2. Go above the minimum standards by advancing the level of performance called for in LEED practices.
3. Use an EMS to assess environmental performance and to manage environmental policy.
4. Create an environmental label or designation specific to the worksite based on a combination of management and technical aspects from LEED, BREEAM, ISO 14001, and others.

Future Research suggested is:

1. Green Construction Practices: this research focused on investigating environmental practices established in green building standards and research, but it can be extended by including social and economic practices that specifically impact the construction phase to provide broader guidance on sustainability management from a contractor's perspective.

2. Project Perspective: this research was focused on LEED 2009 case studies. The same approach can be taken for projects under different certification systems such as LEED v4 or Living Building Challenge.

3. Organization Perspective: this research focused on an overview of the organizational approach to environmental management. However, it could be extended to a more detailed case study evaluating the details of organizational structure, sustainability indicators and reporting systems.

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