Impact of LEED Requirements on the Construction Industry

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On my honor as a University student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments.

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Introduction

There has been increasing concerns on how the construction industry and their engineering practices has had a negative effect on the environment. Devastating impacts include mass consumption of energy and materials, generation of waste, and pollution of air and water. The industry has used about "40% of total energy production, 40% of all raw materials, and 25% of all timber, and is responsible for 16% of water consumption and 35% of carbon dioxide emissions" (Son et al., 2011, p1) worldwide. To resolve these issues, the United States Green Building Council (USGBC) developed a green building rating system known as Leadership in Energy and Environmental Design (LEED) in 1998. Since the publication of LEED, the construction industry has followed these principles to develop structures that are more environmentally friendly.

With the implementation of LEED, construction firms have had to alter several different aspects of their business. This may include realtering their business structures, project delivery methods, safety guidelines, finances, and engineering applications. Through preliminary research, it was discovered that environmentally sustainable firms have improved financially compared to conventional firms that follow the traditional methods of construction. Companies and organizations have also been able to find alternate engineering practices that encourage sustainable building. As a result, energy has been saved, indoor air quality and the health of building occupants has improved, and waste production due to carbon emissions has been reduced. However, some tradeoffs come along with revising different companies' entire business structures and engineering practices to follow LEED requirements. Since employees within the construction industry have to use unfamiliar technology to implement sustainable practices, there is further risk of injury and hazards. The purpose of this research is to see how LEED credits primarily concerning energy, atmosphere and indoor air quality have had strong impacts on the engineering practices that builders use and the construction industry as a whole.

LEED and Its Impact on the Construction Industry

Recent studies have shown that LEED-certified building have accounted for a higher injury rate than traditional non-LEED buildings. Case interviews with actors including LEED designers and their teams were conducted to determine the construction methods chosen to accomplish credits including energy and atmosphere (EA). After completion of the case studies on six different projects, safety risks were determined to come from different EA LEED credits concerning the optimization of energy and performance. New techniques that have been chosen by designers to increase energy performance include the installation of heavy continuous insulation of building shell and evaporative chillers. These methods require increased duration of construction and lifting heavy materials at height and as a result "there was an observed increase in frequency and severity of falls" (Fortunato, 2012 et al., p5). The report mentions that there are also safety risks that come with building vegetated roofs because it involves inexperienced landscaping contractors who are not familiar with work at height. The authors "found that installing photovoltaic panels and atria increased the duration of work at height and time spent installing electrical systems" (Fortunato et al., 2012, p2). As a result, workers, especially those who are inexperienced, are more likely to fall and face the risk of being injured. The LEED credits have caused the situations where sustainable practices are pursued and have resulted in putting worker's at risk of injury and struck-by hazards.

Air pollution, high temperatures, traffic noise, and high energy consumption for heating and cooling purposes each present health and environmental risks, especially in dense, urban settings. However, LEED standards have motivated actors such as firms to solve this problem by designing green walls, which includes the use of vegetation and inorganic matter. These green facades develop oxygen and absorb gaseous pollutants such as nitrogen dioxide, carbon dioxide and ozone compounds that affect air quality. This technology can also be used in external urban environments where pedestrian and vehicular traffic occurs. There has been a direct link to the physical and mental health of individuals according to a study done by researchers at Washington State University. Green walls have been able to reduce risks of obesity, asthma and the likelihood of having heart attacks by lowering blood pressure. It has also improved the efficiency of employees within the workplace, speeding up their reaction times by 12% and helping them focus (Wesolowska et al,, 2019). Green wall technology has also led to feelings of relaxation and better concentration.

A statistical analysis was conducted as well to investigate the respiratory health effects, such as asthma, of residents who have recently moved into the LEED Platinum-certified affordable residential, Melrose Commons V (MCV). This analysis was done to prove that "housing conditions impact asthma morbidity, whereas decreases in indoor allergen and air pollutants can improve asthma symptoms" (Garland, 2012, p 30) This study was conducted on thirteen households with eighteen participants, where twelve of them had asthma. Before moving into the LEED certified building, questionnaires were conducted on each of these participants to determine how their current living conditions impacted their asthma. Conditions included mold, limited exhaust in kitchen and bathrooms, cockroach infestations, and gas stoves. In the LEED certified buildings these conditions were improved by including exhaust and HVAC to improve air quality and the placement of electric stove. Every six months, for eighteen months after moving into MCV, follow up questionnaires were conducted on the participants to see if living conditions have improved. By the study's completion it was determined that there were decreases in detection of symptoms, difficulty sleeping, doctor and emergency room visits, and missed days at work and school (Garland, 2012).

Incorporation of LEED into project design and operations has profoundly yielded significant economic benefits. Although going green may completely reshape a corporation's business strategies and operations, it can benefit construction firms financially in both the short and long term. Shifting to a green construction approach can result in 26% less energy usage, save 13% on maintenance costs, generate 33% less greenhouse gas emissions, and raise return on investment by 6.6% (Lu et al., 2013). An empirical analysis was performed between eleven green and eleven conventional organizations in the construction industry. When short-term performance between these firms were analyzed, the average return on equity for 2007-2009, which measures the profitability of an organization, was calculated to be 17.4% compared to 8.2% for traditional firms (Lu et al., 2013). In fact, green firms performed better with their economic value added, return on capital, and revenue growth. Long term performances show that green corporations are more financially viable too. When it came to measuring the companies' economic profit in excess of all required equity and debt, there was a positive economic profit for green firms, and an economic loss for conventional firms (35.1% compared to -1.74%) (Lu et al., 2013). Changing business structures within the construction industry in accordance with LEED has proven to have economically beneficial outcomes.

Implementation of LEED and demand for sustainable buildings in the United States has caused the construction industry to expand their performance goals in low energy consumption and reduced air emissions. These goals have led to research that determines how project delivery methods and levels of team integration have an impact on the outcomes in sustainable projects. Integration generally states that participants become involved in the project at the correct time and coordinates with other team members. Studies were conducted on eleven projects that determined the relationship between the level of integration and sustainability goals (Mollaoglu-Korkmaz et al., 2013). By the conclusion of these studies, it was observed that if there is a higher level of integration between actors, higher levels of sustainability can be achieved. The second part of this study concerned which project delivery methods should be used to achieve higher levels of sustainability. By the study's completion, it was concluded that design-build and construction management at-risk methods for completing a project results in better achievability of sustainability goals.

Elinor Ostrom's Institutional Analysis and Development Framework

To interpret LEED and its impact on the construction industry, Elinor Ostrom's (2011) institutional analysis and development (IAD) framework will support the creation of a multi-tier conceptual map that is summarized in figure 1. External variables such as the LEED requirements that are followed within the construction industry may cause an action situation to occur. Within the action situation, actors such as construction firms have to make "policy decisions within the constraints of a set of collective-choice rules" (Ostrom, 2011, p11). These decisions can result in different potential outcomes that can be evaluated and compared to outcomes that may have been achieved under alternative institutional arrangements. Outcomes may include the alterations to business structures, project delivery methods, and engineering practices. These outcomes can then be evaluated to see if environmentally sustainable firms' finances, energy performance, carbon emissions and health have improved, or if worker safety has declined.

The IAD framework will function as the foundation to properly analyze the research that was conducted and summarized in the upcoming results section. The LEED standards are a form of “rules-in-use” according to figure 1 and can be classified as an external variable since they have a direct influence on the action situation. In the construction industry, the action situations would involve multiple actors such as designers, architects, project managers, and constructors who collaborate to produce products, services and other actions that are shaped by the external variables. As a result of engagement within the action situations, construction professionals would realize outcomes that may occur from their interactions such as reductions in carbon emission and improvements in energy performance, indoor air quality, worker safety, and finances. These outcomes can always change if external variables such as LEED are revised or if actors within the action situation want to use a different approach to improve their outcomes. As shown in the figure below, the IAD framework functions as a cyclical process so that previous outcomes can be compared to more recent outcomes that have resulted from an action situation. In the case of the construction industry, evaluative criteria such as different firms’ financial and sustainable performance as well as comparisons between green and conventional firms were used. In summarization, the IAD framework will be used to determine LEED’s influence on several different aspects of the construction industry and see how it differs from the traditional building approaches that were used.

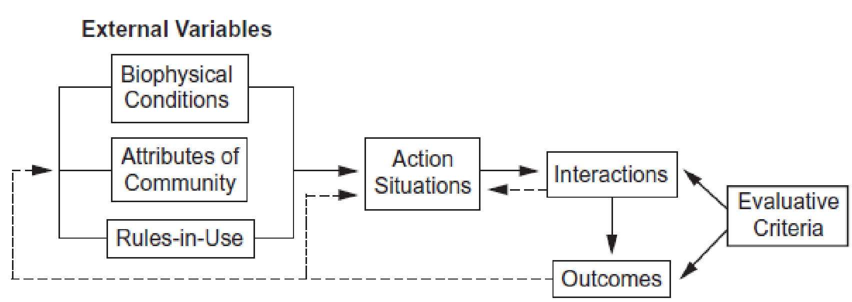

Figure 1. Framework for institutional analysis containing the external variables that may influence the decisions made by actors within the action situation. Interaction with other actors may occur and can result in outcomes that can be analyzed and evaluated. (Image Source: Ostrom, 2011)

Methods for Research

To explore the impacts that LEED requirements have had on the construction industry, a series of empirical studies and interviews were conducted to review, compare and analyze different construction firms' finances, sustainability reports, and constructor's' perspectives. Through the use of empirical studies, five different public construction companies' annual, sustainability and safety reports from 2012 to 2018 were quantitatively analyzed to determine if there were relationships between the LEED credits and its influence on the construction industry. Annual reports were reviewed to find if each firm's finances and operating activities have been affected by the accreditation of LEED. Safety and sustainability reports for each of these companies were analyzed to observe if there have been improvements in worker safety, energy performance, and greenhouse gas (GHG) emissions resulting from LEED. After firms were analyzed individually, the conventional and sustainable firms were compared to conclude if green contractors are more financially viable and have seen improvements in worker safety, greenhouse gas emissions, and energy performance. The five firms that were selected are shown in the table 1, along with their rankings as environmental, green design, and green contracting firms which were taken from the *Engineering News Record* (ENR). ENR is magazine that provides news, analysis, data, and rankings for the construction industry worldwide. As seen in table 1, construction firms such as Stantec and AECOM, can be described as sustainable and can be compared to conventional firms such as Balfour Beatty and Skanska. The primary similarity between these four firms is that they all focus residential, and commercial building such as offices, hospitals, airports, retail, and restaurant. Fluor was also selected to see how construction firms who specialize in other types of construction like infrastructure, oil, gas, and power have been impacted by LEED.

Engineering News Record Rankings 2019			
Company	**Environmental Ranking**	**Green Design Ranking**	**Green Contractor Ranking**
Skanska	N/A	N/A	6
AECOM	1	2	2
Balfour Beatty	N/A	N/A	46
Stantec	8	8	N/A
Fluor	5	N/A	N/A

Table 1. Environmental, Green Design, and Green Contracting Ranking based off the 2019 Engineering News Record lists found on ENR.com. Rankings are for the five firms that were selected for research. (Created by Traynor, 2020) Note. Data for ENR rankings are from ENR Top 100 Green Building Contractors (2019), ENR Top 100 Green Building Design Firms (2019), and ENR Top 200 Environmental Firms (2019).

Primary sources were used as well to gather information about construction professionals' perspectives on how LEED standards may have impacted the construction industry as a whole. Two interviews were conducted with employees who work at AECOM and Stantec, the most sustainable firms out of the five that were selected. The goals of these interviews were to learn about each professional's role in the construction industry in relation to LEED, and the engineering practices they use to reduce carbon emissions, and improve energy performance and indoor air quality. Questions about alterations in business structures and project delivery methods used, worker safety, and their perspectives on whether they have seen improvements in sustainability in this industry were asked as well.

Research and Results

After completing research, it was determined that LEED has had a strong impact on sustainable firm's finances, safety, energy performance, carbon emissions, and engineering applications when compared to conventional firms. The sustainability reports helped determine that there have been improvements in both energy performance and GHG emissions for all the firms that were analyzed. The sustainability and safety reports also concluded that sustainability has had a positive impact on worker safety for sustainable firms rather than conventional firms.

However, the interviews emphasize that there may be no direct link between the “rules-in-use” and the outcome of worker safety. The annual reports helped determine that green firms have seen improvements in revenue, whereas for other firms, there was little to no change. The interviews allowed me to learn more about each professional’s role in sustainability, how building standards have improved since the incorporation of LEED, sustainability goals that firms are aiming to achieve, and the engineering practices that they have used to reduce greenhouse gas emissions, and improve energy performance and indoor air quality.

The construction industry follows the same standards in terms of measuring GHG emissions. Generally, GHG emissions and energy performance are split into three primary scopes and are measured in metric tons. However, the sum of the first two scopes are shown in figure 2 below since most firms do not record scope three measurements. Scope one emissions include direct emissions such as office and on-site fossil fuel combustion as well as vehicle and equipment fuel consumption that are controlled by the firm. Scope two emissions involve indirect emissions from the generation of purchased electricity. Beginning with sustainability reports from 2012 for all five firms, scope 1 and 2 emissions for every other year until 2018 were recorded. As seen in figure 2, all five firms experienced a decrease in both emission scopes. This shows that although the selected firms were classified as conventional or green, both have seen positive results with carbon emissions and energy performance. For instance, Skanska recorded of value of 430,721 metric tons for the scope 1 and two emissions total in 2012, and this value decreased by almost 28% over six years with a recorded value of 311,997 metric tons in 2018. A more complex breakdown of the exact values of each scope in metric tonnage for each of the five firms from 2012 to 2018 can be found on table A1 in the Appendix A as well. Using Elinor Ostrom’s IAD framework, this indicates that external variables such as LEED, has successfully encouraged actors within construction firms to earn credits related to energy and atmosphere, as well as indoor air quality by altering their engineering practices to achieve sustainability goals concerning carbon emissions and energy performance. Since the recorded values for scope 1 and 2 emissions have been decreasing over the past six years, it also is likely that these rates will continue to decrease in the future due to LEED's impact.

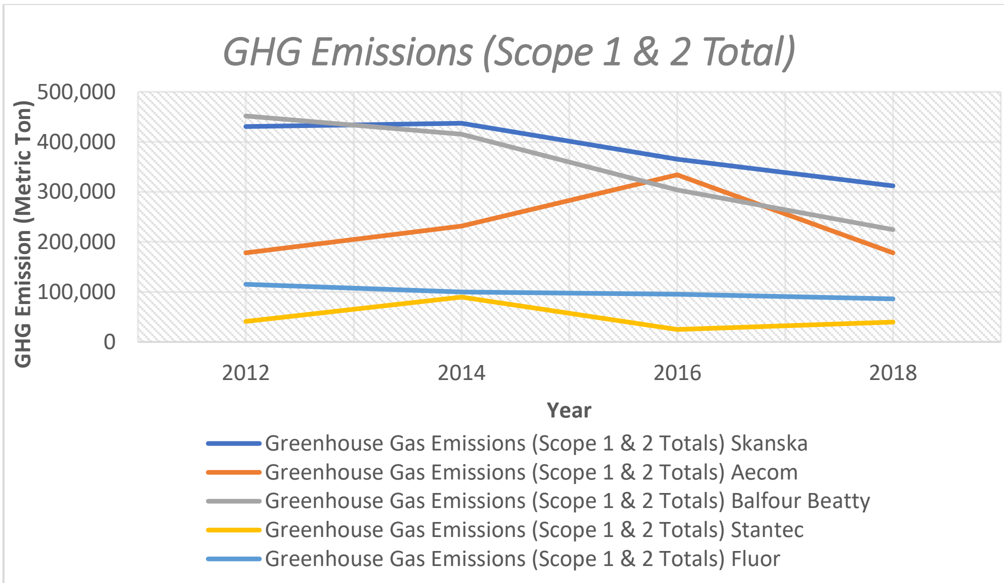

Figure 2. Graphical representation of the combined scope 1 & 2 emissions for the five construction firms based off each of their sustainability reports from 2012-2018. Data for emissions for Skanska obtained from sustainability reports Skanska (2013), Skanska (2015), Skanska (2017), and Skanska (2019). Data for emissions for AECOM obtained from sustainability reports AECOM (2013), AECOM (2016), AECOM (2017), and AECOM (2019). Data for emissions for Balfour Beatty from annual reports Balfour Beatty (2013), Balfour Beatty (2015), Balfour Beatty (2017), and Balfour Beatty (2019). Data for emissions for Stantec obtained from sustainability reports Stantec (2013), Stantec (2015), Stantec (2017), and Stantec (2019). Data for emissions for Fluor obtained from sustainability reports Fluor Corporation (2013), Fluor Corporation (2015), Fluor Corporation (2017) and Fluor Corporation (2019). (Created by Traynor, 2020)

The sustainability reports were also utilized to determine how changes in engineering practices due to LEED has impacted worker safety. Comparisons between firms proved to be difficult for worker safety since firms used different rates to record accidents. For Skanska, the lost-time accident rate (LTAR), which is a formula that multiplies the number of employees by

1,000,000 hours and is divided by the total labor hours, was recorded. For this conventional firm, there were no improvements in LTAR and the total number of fatalities increased from two deaths in 2012 to five deaths in 2018 as shown in table 2. This analysis indicates that conventional firms like Skanska, have not seen improvements in worker safety since the incorporation of LEED which indicates that it may have no impact on these firms.

Table 2. Skanska's summarized accident report obtained from their sustainability reports from 2012 to 2018. (Created by Traynor, 2020)

Skanska Accident Report		
Year	**LTAR**	**Fatalities**
2012	3.5	2
2014	3.3	3
2016	2.8	3
2018	3.5	5

Note. Data for Skanska obtained from sustainability reports Skanska (2013), Skanska (2015), Skanska (2017), and Skanska (2019).

AECOM, on the other hand, has seen major improvements in their total recordable incident rate (TRIR) and their lost workday case rate (LWCR). Their TRIR is similar to Skanska's LTAR, the difference being that instead of multiplying by 1 million hours, AECOM multiplies by 200,000 hours. The LWCR uses the number of days missed rather than the number of employees and multiplies this number by 200,000 hours and divides by the total number of labor hours worked. According to table 3, both of AECOM's rates have decreased over six years with its TRIR and LWCR performance beginning at 0.89 and 0.30 in 2012, and decreasing to 0.29 and 0.06 in 2018, respectively. The 2018 safety report for AECOM also mentions that since 2010, the overall TRIR performance has decreased by 75% and the LWCR has decreased by 90% (AECOM, 2019) even though the number of employees at this firm has almost doubled from 46,800 to 87,000 as seen in table C1 in the Appendix C. These decreases in LWCR and TRIR performance shows that the external variable, LEED, may have a link to the outcomes which show improvements in worker safety for green firms since the number of incidents involving injuries have dropped significantly even though more employees were hired. Stantec, which is a highly ranked environmental firm like AECOM, has also seen improvements in their TRIR, with a 47% decrease since 2013 according to their 2018 sustainability report (Stantec, 2019). Also, according to table B1 in the Appendix B, Stantec has had no more than one fatality each year. These results once again indicate that green firms have seen significant decreases in risks of hazards over time. The summarized accident reports for Fluor and Balfour Beatty are shown in table B2 and table B3 in Appendix B as well. For both of these firms there are no significant changes in their lost time incident rates (LTIR), minor injury rates (MIR), accident frequency rates, and total case incident rates. These results indicate that sustainable firms such as Stantec and AECOM have seen major improvements in safety compared to traditional firms, however, since Fluor has seen no changes in their rates, there may be no direct relationship between LEED and its impact on safety.

Table 3. AECOM's summarized accident report obtained from their sustainability reports from 2012 to 2018. (Created by Traynor, 2020)

AECOM Accident Report		
Year	**TRIR**	**LWCR**
2012	0.89	0.3
2014	0.37	0.06
2016	0.35	0.06
2018	0.29	0.06

Note. Data for AECOM obtained from safety reports AECOM (2013), AECOM (2016), AECOM (2017), and AECOM (2019).

The annual reports were used to determine if there were any relations between LEED and each firm's financial performance. Before proceeding with comparisons for all five firms, the revenues for Stantec and Balfour Beatty had to be converted to U.S. dollars since they conduct financial analysis using Canadian and British currency. Skanska, has seen major improvements in their revenue over the past six years even though they have lost almost half of their employees according to table C1 in Appendix C. From 2012 to 2018, Skanska has increased their gross revenue by over $40 billion according to table 4. Along with the significant improvements in their financial results, Skanska mentioned in their 2018 annual report that 85% of their total central debt is green and 46% of their revenue that has been generated from construction is considered to be "green" and "deep green" (Skanska, 2019). These two classifications are shaped by rating systems such as LEED, BREEAM, and EU GreenBuilding and assist them with reaching their goals of "Net Zero Primary Energy, Near Zero Carbon Construction, Zero Sustainable Materials, Zero Hazardous Materials, Zero Waste, and Net Zero Water" (Skanska, 2019). This information is a strong indicator that green construction and LEED standards has heavily impacted firms such as Skanska financially by allowing large portions of their revenue to come from sustainability. AECOM has also been financially successful with its revenue tripling since 2012 from $5.18 billion to $18.2 billion in 2018. Although there is no breakdown of how much revenue was generated from sustainability, since AECOM is one of the top sustainable firms across the world, their revenue growth is due to the increase in the number of sustainable projects the firm has completed. Stantec has seen its revenue almost triple as well based off of table 4. According to their 2012 sustainability report, 34% of their annual revenue during that year was focused on environmental services such a water supply treatment and management, waste collection, environmental site management, ecosystem restoration, and more (Stantec, 2013). In 2018, these environmental services were split into more complex categories such as water, environmental services, and energy and resources with the sum of these services being equivalent to approximately 61% of Stantec's gross revenue (Stantec, 2019). The increase in revenue generated from the environmental services points out that LEED has cause actors to change the practices that are used in construction to achieve better sustainable results. This additional evidence also exemplifies that LEED has become of larger factor in its financial impact on the construction industry. Unfortunately, more traditional firms such as Fluor and Balfour Beatty, have experienced losses in revenues as seen in table 4 and share limited amounts of information about what portions of their revenue have been generated from green contracting. These results suggest that LEED and other rating systems have shaped the environmental services that sustainable firms provide and has led them to greater financial results compared to more conventional companies.

Table 4. Numerical representation of the annual revenues every other year from 2012 to 2018 for each of the five construction firms. (Created by Traynor, 2020)

Annual Revenue ($ billions)					
Year	**Skanska**	**AECOM**	**Balfour Beatty**	**Stantec**	**Fluor**
2012	$ 129.35	$ 5.18	$ 10.24	$ 1.43	$ 27.58
2014	$ 143.33	$ 4.89	$ 7.50	$ 1.92	$ 21.53
2016	$ 145.37	$ 17.99	$ 7.33	$ 3.27	$ 19.04
2018	$ 171.73	$ 18.20	$ 7.16	$ 3.26	$ 19.17

Note. Data for Skanska obtained from annual reports Skanska (2013), Skanska (2015), Skanska (2017), and Skanska (2019). Data for AECOM obtained from annual reports AECOM (2013), AECOM (2016), AECOM (2017), and AECOM (2019). Data for Balfour Beatty from annual reports Balfour Beatty (2013), Balfour Beatty (2015), Balfour Beatty (2017), and Balfour Beatty (2019). Data for Stantec obtained from annual reports Stantec (2013), Stantec (2015), Stantec (2017), and Stantec (2019). Data for Fluor obtained from annual reports Fluor Corporation (2013), Fluor Corporation (2015), Fluor Corporation (2017) and Fluor Corporation (2019).

Interviews with two construction professionals at AECOM and Stantec were conducted to gain more insight about the sustainable engineering practices that are used, worker safety, and how LEED has altered different construction firms’ business structures and delivery methods. The first interview was done with Emily McDuff, an energy engineer at AECOM. Her role at this firm consists of working with the energy efficiency team in Washington D.C. and keeping track of GHG emissions for existing buildings. During the interview, Emily mentioned that since

"LEED is now becoming a part of the conversation," construction in larger cities and new schools now require LEED Silver certifications. This means that for construction companies such as AECOM, their goal is to reach a minimum of 50 points which is determined by the credits they have achieved for indoor air quality, energy, atmosphere and more. Since LEED is becoming a requirement, the standards have motivated firms in construction to achieve better rates for energy performance and costs, carbon emissions and indoor air quality. Emily stated that designing structures to become net zero in carbon emissions and energy has now become a goal. This can be simply defined as balancing carbon emissions and energy usage with carbon removal and renewable energy so that the net value for emissions and energy is zero. Emily commented that she has seen major improvements in both GHG emissions and indoor air quality in LEED certified buildings through the technologies that they have adopted during the design phase as well. This includes the use of green roofs with trees and gardens to reduce GHG emissions and using outdoor air for filtering rather than filtering air from scratch to save energy. This statement specifies that LEED has become a more well-known rating system and has caused firms to focus more on sustainable design by changing the materials and technologies that they use in order to meet sustainability requirements.

Although AECOM is involved in all aspects of the project lifecycle, Emily mentioned that LEED and sustainability are heavily utilized during the design phase. The design phase involves creating sustainable systems through building information modeling software, such as Revit and calculating expected targets for energy performance, indoor air quality and carbon emissions. She explained that this is why her firm heavily relies on design-build and design-bid-build project delivery methods for sustainability. Emily also pointed out that with sustainability becoming a larger part of the construction process, business structures are being altered by adding new teams such as the energy efficiency team she is on. One final thing she added about LEED's impact on the engineering applications used was that "technologies would not be mainstream and LEED functions as a guidebook so it could be streamlined and become a standard across the country." This means that since more people both inside and outside of the construction industry have become more aware of LEED, the software, business structures, and project delivery methods that have been traditionally followed are being altered to comply with thee standards.

The second interview was done with Victoria Civitillo, a sustainability project manager at Stantec. She primarily works on modeling new, sustainable MEP (mechanical, electrical and plumbing) systems for existing buildings, which comprises of about 70% of Stantec's work. From her experiences with this company, she mentioned that LEED is heavily utilized during the design, and operations phases of the project lifecycle. She stated that during operations she uses "MEP modeling to calibrate how systems do in the long run. You can check a building's energy performance and see how much money in operations costs is being saved." She added that this energy modeling process would cease to exist without LEED since this is a part of the certification process and can help you receive a certain number of points to achieve silver, gold, or platinum certification. Another engineering application that is becoming more common is the analysis of different materials such as steel and cement, because these materials have a strong impact on carbon emissions. This shows that technologies and engineering applications have been developed to measure energy performance and costs as well as carbon emissions to determine if these rates comply with LEED. An interesting topic that Victoria brought up was that although there have been improvements in injury rates according to Stantec's safety reports, she said that she has seen no correlation between worker safety and sustainability. She stated that the injury rates of workers heavily rely on the safety standards that each construction firm enforces. This explains why there has been almost no change in injury rates for some of the construction firms that were analyzed.

At the end of the interview, Victoria stated that since LEED and sustainability have become increasingly popular in the industry, different cities are beginning to pass legislations that promote greenhouse gas regulations. An example is Local Law 97, which Victoria mentioned was put into effect in New York City and puts a cap on each building's carbon footprint, and if a building surpasses the limitations, fines are enforced. Emily McDuff mentioned that something similar is being done in Washington D.C. where buildings need to be ENERGY STAR certified. This means that caps for energy efficiency and carbon footprints must be met, or else fines will be enforced as well. These new legislations indicate that building rating standards such as LEED have not only impacted the construction industry, but is now changing the government's views on sustainability.

Discussion

After completing my research and compiling all of the results, it became clear that LEED has had not only a strong impact on the construction industry, but other social institutions as well. Although LEED was specifically developed by the USGBC to establish a set of standards that firms within the industry could follow to construct buildings to be more environmentally friendly, my research showed that these standards also have an impact on the local, state and federal government. With burning fossil fuels, ozone depletion, and limited energy resources becoming a rising concern across the world, actions to combat climate change have become increasingly popular. Since the construction industry is only a small part of the problem with climate change, other industries and political institutions need to take measures similar to that of the USGBC to reverse the harmful effects that technology, materials, and other resources have on our environment. The research that I completed shows that by creating a set of standards, rules, laws, or policies relating to sustainability for each industry, society will become more aware of the issues with our changing environment. Creating new standards will also encourage the individuals within each business to take action.

There were two main limitations that I encountered throughout the process. The first limitation was the difficulty with locating the annual and sustainability reports for different construction firms since a majority of companies within this industry are listed as private. However, the Engineering News Record proved to be a valuable resource in assisting me with locating companies that were publicly owned. Also, it was difficult to analyze and determine each firm's finances to LEED since there was limited public information available about how much of sustainable construction was responsible for the total revenue generated. Another limitation I encountered was the lack of availability of resources that could be used to contact employees at each of the firms that were selected for my research. I primarily used LinkedIn to contact construction professionals, and out of the 30 individuals I reached out to, only two responded. Although I obtained a lot of information from my interviews with Emily and Victoria, hearing from the perspectives of individuals at more traditional firms would have allowed me to gain more insight on how conventional firms are approaching sustainability.

One thing I would do differently in the future is review how other building rating standards along with LEED have impacted the construction industry. During my interviews with Emily and Victoria, they brought up information about how they were certified energy managers (CEM) and have received certifications from WELL AP, which promotes human health by improving indoor air quality. Another thing that I would do differently is to reach out to more employees and start my interview process earlier. Although I began this process a month before I planned on submitting the second half of my thesis, I was shocked by how few people returned my direct messages and emails. One final thing I would do differently since it was brought up in both my interviews, is conduct more research on how LEED has impacted the government's views on sustainability. Before hearing about ENERGY STAR and Local Law 97, I had never come across information about regulations that have been passed by city officials to promote sustainability in the construction industry.

Since I have been involved in construction for a few years now, research was primarily conducted so I could become better informed on what LEED is and how it has impacted the industry. Before I began research, I had no idea what LEED was other than the fact that it was related to sustainability. With some guidance from Professor Foley, I learned how to perform research from a social point of view rather than analyzing the technical aspects of LEED. I originally started this research with the intent of using all the information to become better informed about this rating standard since I was planning to pursue a career in sustainability in construction. However, I am now planning to pursue a career in defense contracting and now understand how large of an impact sustainable rating standards such as LEED can have on an industry and the people within it. I hope my research that I have conducted will prove to be useful when I come across challenges with sustainability in defense contracting.

Conclusion

Although LEED was established in 1998, the construction industry did not heavily rely on these standards for at least a decade since reports on sustainability did not become readily available until the early 2010s for most public firms. However, based on the evidence obtained from the annual, safety and sustainability reports as well as the interviews, it is clear that LEED has had a major impact on the construction industry and the engineering applications that are used. All of the reports show that there have been improvements in energy performance and carbon footprints based on the two emissions scopes that were analyzed. Green firms have also seen improvements in their revenue, as well as portions of their revenue generated from sustainable practices when compared to more traditional firms. Also, although sustainable firms have seen improvements in worker safety, it is inconclusive if the injury rates have a direct relationship with LEED and this requires more research. Based off of the interviews, LEED has changed the engineering applications that are used to improve carbon emissions, indoor air quality and energy performance. According to Emily and Victoria, new applications include designing green roofs, altering air filtering technologies, MEP modeling, and material analyses for carbon emissions. The interviews concluded that LEED has altered business structures by creating new teams, is primarily utilized in the design and operations phases, and has changed building standards to meet emissions and energy caps. It was mentioned by both interviewees that they have received other certifications related to health and sustainability. Further research should be conducted to determine how CEM and WELL AP has impacted construction professionals' awareness and knowledge of sustainability. Emily and Victoria also stated that with the incorporation of LEED, local governments are beginning to understand the importance of sustainability and are beginning to pass legislations and other standards. One of the next steps that should be taken would be to review these legislations and determine their relationships with LEED. The research helped uncover that LEED's impact on society goes beyond the construction industry. With more people becoming aware about the industry's impact on the environment, the government and other organizations are developing new laws and standards to promote sustainability.

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Appendix A: Scope 1 & 2 Emission Totals for Five Construction Firms

Table A1. Numerical representation of the combined scope 1 & 2 emissions for the five construction firms based off of each of their sustainability reports from 2012 to 2018. (Created by Traynor, 2020)

Scope 1 & 2 Emissions								
Company	**Scope 1 (Metric Ton)**				**Scope 2 (Metric Ton)**			
	2012	**2014**	**2016**	**2018**	**2012**	**2014**	**2016**	**2018**
Skanska	371,158	367,791	312,800	275,173	59,563	60,494	52,704	368,244
AECOM	18,371	137,546	52,616	21,669	67,688	196,581	178.728	156,418
Balfour Beatty	320,136	295,219	222,485	175,065	131,658	120,126	81,657	49,365
Stantec	11,328	11,734	-	10,333	29,586	35,112	-	29,586
Fluor	43,000	55,000	52,000	41,000	16,000	100,000	95,000	86,000

Note. Data for emissions for Skanska obtained from sustainability reports Skanska (2013), Skanska (2015), Skanska (2017), and Skanska (2019). Data for emissions for AECOM obtained from sustainability reports AECOM (2013), AECOM (2016), AECOM (2017), and AECOM (2019). Data for emissions for Balfour Beatty from annual reports Balfour Beatty (2013), Balfour Beatty (2015), Balfour Beatty (2017), and Balfour Beatty (2019). Data for emissions for Stantec obtained from sustainability reports Stantec (2013), Stantec (2015), Stantec (2017), and Stantec (2019). Data for emissions for Fluor obtained from sustainability reports Fluor Corporation (2013), Fluor Corporation (2015), Fluor Corporation (2017) and Fluor Corporation (2019).

Appendix B: Accident Reports for Stantec, Fluor, and Balfour Beatty

Table B1. Stantec's summarized accident report obtained from their sustainability reports from 2012 to 2018. (Created by Traynor, 2020)

Stantec Accident Report		
Year	**TRIR**	**Fatalities**
2012	0.65	0
2014	0.62	1
2016	0.65	0
2018	0.41	1

Note. Data for Stantec obtained from sustainability reports Stantec (2013), Stantec (2015), Stantec (2017), and Stantec (2019).

Table B2. Fluor's summarized accident report obtained from their sustainability reports from 2012 to 2018. (Created by Traynor, 2020)

Fluor Accident Report			
Year	**TCIR**	**Fatalities**	**Days Away or Transferred Cases**
2012	0.31	3	-
2014	0.32	0	0.14
2016	0.43	0	0.17
2018	0.36	2	0.21

Note. Data for Fluor obtained from sustainability reports Fluor Corporation (2013), Fluor Corporation (2015), Fluor Corporation (2017) and Fluor Corporation (2019).

Table B3. Balfour Beatty's summarized accident report obtained from their sustainability reports from 2012 to 2018. (Created by Traynor, 2020)

Balfour Beatty Accident Report				
Year	**LTIR**	**MIR**	**Accident Frequency Rate**	**Fatalities**
2012	0.26	0.06	0.16	8
2014	0.27	0.05	0.15	6
2016	0.22	0.03	0.12	5
2018	0.15	0.04	0.09	2

Note. Data for Balfour Beatty obtained from annual reports Balfour Beatty (2013), Balfour Beatty (2015), Balfour Beatty (2017), and Balfour Beatty (2019).

Appendix C: Total Number of Employees at Each Firm

Table C1. Total number of employees at each of the five construction firms from 2012 to 2018. This table was utilized to see how the total number of employees fluctuated as accident rates changed by year. (Created by Traynor, 2020)

Number of Employees					
Year	**Skanska**	**Aecom**	**Balfour Beatty**	**Stantec**	**Fluor**
2012	56,618	46,800	50,000	12,700	40,000
2014	57,866	43,300	36,000	15,000	37,500
2016	41,000	87,000	43,000	22,000	61,600
2018	38,000	87,000	26,000	22,000	53,300

Note. Data for Skanska obtained from annual reports Skanska (2013), Skanska (2015), Skanska (2017), and Skanska (2019). Data for AECOM obtained from annual reports AECOM (2013), AECOM (2016), AECOM (2017), and AECOM (2019). Data for Balfour Beatty from annual reports Balfour Beatty (2013), Balfour Beatty (2015), Balfour Beatty (2017), and Balfour Beatty (2019). Data for Stantec obtained from annual reports Stantec (2013), Stantec (2015), Stantec (2017), and Stantec (2019). Data for Fluor obtained from annual reports Fluor Corporation (2013), Fluor Corporation (2015), Fluor Corporation (2017) and Fluor Corporation (2019).