Estimating for Sustainable Construction: Challenges and Methodologies for Quantifying Green Building Practices

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Abstract

Here, sustainable construction is meant to progressively reduce environmental impact, employing energy efficient technologies, organic materials and innovative building practices. Green building costs are difficult to estimate because there is such a combination of costs: higher upfront and lower long term; availability of materials; and environmental benefits in the financial estimate. Life Cycle Assessment (LCA), Integrated Project Delivery (IPD) as well as energy modeling are methodologies provided among others to estimate sustainable projects in this paper. A few case studies are provided that demonstrate how these methodologies have been applied to real world projects, highlighting both the gritty and glamorous sides of green construction estimation. The paper also talks about the policy framework and the certification such as LEED that motivate for sustainable practices.

Keywords: Sustainable Construction, Green Building Practices, Cost Estimation, Life Cycle Assessment, Energy Modeling, LEED, Integrated Project Delivery, Sustainable Materials, Environmental Impact, Construction Estimation, Policy Incentives, Certification.

Introduction

For a long time, the construction industry is known as a leading contributor to environmental deterioration, which accounts for 40 percent of all global energy consumption and 30 percent of greenhouse gas emissions [1]. For example, the need to use sustainable building practices that minimize environmental impact from the building’s conception to its eventual destruction is hugely increasing with the increasing of the climate. What sustainable construction does is to address these issues by incorporating eco friendly materials, energy effective systems and waste reduction techniques into the building process.

However, estimating costs and benefits of green buildings projects meaningfully is difficult. The traditional construction cost estimation methods mainly include upfront cost, but lack of the energy consumption and maintenance cost over long term [2]. Compared to green building practices, lifecycle cost, which involves the overall economic value of sustainable materials and energy efficient systems, is emphasized in these.

Thus, methodologies for estimating for sustainable construction are considerably more complex than typical building projects. As well as the cost and availability of sustainable materials, estimators need to consider potential energy savings and the environmental impact of the construction process. This paper goes further to explore these challenges, and discuss the methodologies employed in costing sustainable construction projects. It also reviews the use of green building certifications (e.g., LEED) to shape estimation practices, as well as case studies of successful green building projects.

Challenges in Estimating Sustainable Construction Projects

High Upfront Costs of Sustainable Materials

Eco friendly materials are significantly more expensive upfront than traditional building materials and thus present one of the biggest challenges in estimating sustainable construction projects. Because sustainable materials, such as recycled steel, low-emission glass, bamboo, low VOC (volatile organic compound) paints often have to be sourced from relatively few, geographically scarce locations, are produced using complex processes, their price is higher than average [3]. For instance, recycled steel can be anywhere from 5–15 percent more expensive if it requires additional process to reclaim and refine the material [4].

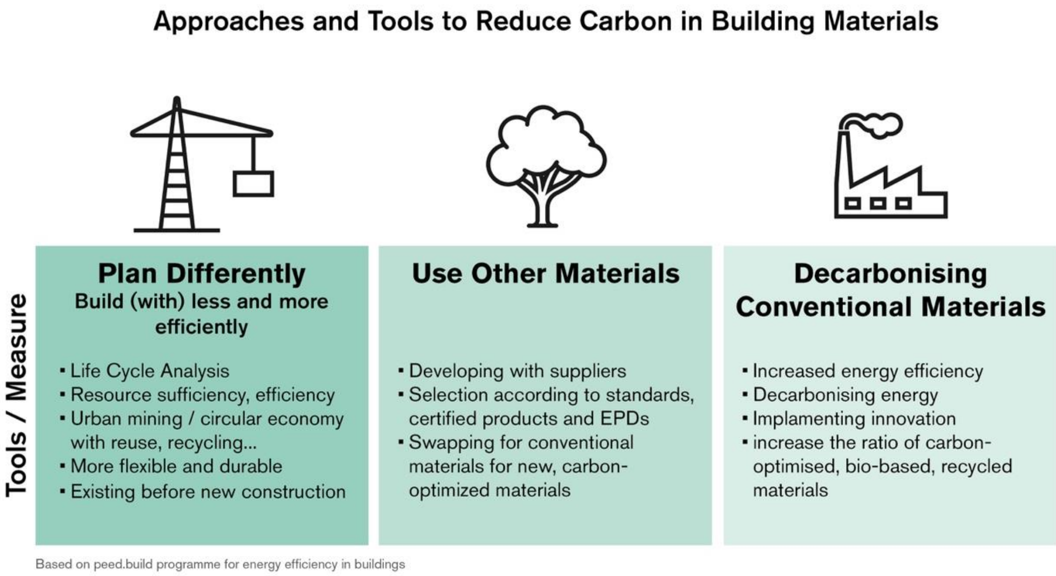

Figure 1 : Approaches and tools for reducing carbon emissions in building materials through improved planning, alternative material use, and decarbonization of conventional materials. Based on the PEED.build programme for energy efficiency in buildings.

Also, the variability in the supply chain for green materials must be accounted by estimators. In the midst of rising demand of sustainable products, material shortages and price volatility can make the estimation process even worse. For an example, a miss out on of sustainably harvested timber or quickly renewable materials like bamboo may cause cost overrun in the event alternative and less sustainable materials should be substituted [5].

While there are certainly challenges, the initial high costs of these materials can be compensated by long term maintenance and operational savings, energy use, output efficiency, etc. An example might be energy efficient windows and insulation products that initially may be more costly but can greatly cut a building's energy expense, thus reducing utility bills over time. But accurate prediction of these savings is dependent on sophisticated energy modeling tools that add another complexity to the estimation [6].

Energy Modeling and Predicting Operational Savings

The use of energy modeling is important in estimating for sustainable construction projects for the purposes of determining long term reductions in energy use. New energy efficient systems, including solar panels, geothermal heating, and smart building technologies, do require up front investments which need to be justified by projected operational savings [7].

Energy modeling tools, including EnergyPlus, eQUEST, and IES-VE, provide estimators with the ability to use simulated energy performance of a building based on its design, location and habits of its occupants. Finally, these models are useful data for knowing what a building will do under different operating situations such as the amount of day lighting or availability for natural or solar ventilation in the future [8]. Unfortunately, these simulations depend greatly upon assumptions about future energy prices, occupant behavior, and climate conditions, and thus introduce an element of uncertainty into the estimation process.

With the complex nesting of advanced technologies integrated into energy modeling, such as Building Information Modeling (BIM), there is more complexity to the ways energy modeling and simulations can shape sustainability. BIM allows for not only energy but also material durability, waste generation and a precise build of the overall environmental footprint of the building so that more accurate lifecycle costs can be provided [9]. But those technologies come at a cost, at least in terms of learning what it is you're attempting to estimate.

Figure 2: **Infographic explaining LEED certification and its benefits, including reduced carbon footprints, improved indoor environmental quality, and enhanced productivity in sustainable buildings.**

Environmental Impact Quantification

Estimating the environmental benefits of green building practices is a major challenge in estimating for sustainable construction. For that, evaluators have to go beyond classic financial metrics and incorporate metrics such as carbon emission, energy efficiency, water consumption and waste reduction in their estimates [10]. Financial estimation of these environmental benefits is needed to obtain green building certifications (e.g. LEED or BREEAM), but the number can be difficult to translate into financial terms.

Life Cycle Assessment (LCA) is often used to estimate the environmental impact of a building during its life time. LCA computes environmental impacts associated with the energy and materials used in the building's construction, operation and demolition to provide an estimate of the positive environmental effects of using sustainable processes [11]. But performing an LCA requires access to detailed information about the sourcing, production and disposal of materials, and this may not be readily available. Moreover, future environmental conditions of the building must be assumed in LCA models that use the estimators, thus adding further uncertainty into the estimation [12].

Methodologies for Estimating Green Building Practices

Life Cycle Assessment (LCA)

Life Cycle Assessment (LCA) is a widely used method defining the environmental impact of green building projects. LCA not only offers a life cycle view of the environmental performance of a building, but also consider the energy, materials, and water consumption of the entire building during the whole building lifecycle including the building edge (material extraction, construction, operation, and demolition) [13].

In particular, LCA is a useful means of comparing the environmental impact of different materials and technologies. For instance, LCA may analyze the carbon footprint of recycled steel as compared with traditional steel, or the long-term water savings consequent on the installation of a rainwater harvesting system [14]. LCA quantifies what these environmental impacts are and how these impacts can be accounted for in cost models, in order to justify the higher upfront green building materials.

Nevertheless, there are challenges with the application of LCA to estimating. Getting accurate LCA data is not always easy, as material and technology environmental performance information is often present at too high a level of abstraction. Also, LCA necessarily presumes future environmental context into which the building is going to be operating, including possible variation in climate, energy prices and availability of water. While these assumptions add uncertainty to the estimation process, discrepancies between estimated and actual environmental benefits result [15].

Integrated Project Delivery (IPD)

Emerging as a methodology for managing sustainable construction project, Integrated Project Delivery (IPD) is defined. IPD, unlike traditional delivery methods, brings architects, engineers and contractors all working together during the project lifecycle. In particular, this approach is very useful in the case of sustainable construction, where the estimation of costs needs to be aligned with environmental objectives [16].

IPD works with the sustainability objectives embedded before the project is designed, leading to the project designers and constructors selecting sustainable and energy efficient materials, designing energy systems and sustainable practises are incorporated from the outset. IPD allows for the involvement of estimators in the design phase of the project to ensure that cost estimates preserve the project’s sustainability goals and are less susceptible to cost overrun and skew the project such that it misses certification benchmarks [17].

Cost balance between upfront costs and long term sustainability goals is one of the key benefits of IPD. IPD integrates expertise from sustainability consultants, energy modelers, and material suppliers to enable project teams to make informed trade off decisions for short term expenses and long term savings. A project team using IPD for example invests in more expensive energy efficient windows because there is a projected savings in energy over the lifetime of a the building [18].

Case Studies: Successful Estimation in Sustainable Construction

The Edge Building, Amsterdam

Worldwide, the Edge in Amsterdam is one of the most sustainable office buildings in the world, with the highest ever BREEAM, so not surprisingly it is the standard chosen for this project. The success of the project in sustainable construction estimation was based on the extensive use of energy modeling and LCA to maximize the performance of the building. Advanced simulations were used to develop estimators for the energy consumption of the building as a function of its design, including a solar panel facade and a geothermal heating system. Through these simulations, the project team was able to accurately predict the amount of energy savings that would occur and design these savings into the overall cost estimate [19].

LCA was used to quantify the environmental benefits of the use of recycled materials and low energy systems, helping the team make the right material and energy use decisions. This resulted in a 70 percent reduction in building’s operational costs and served to underscore the value of performance based estimation in the green building construct [20].

Bullitt Center, Seattle

The greenest commercial building in the world isn't simply green; it's also successful: The Bullitt Center in Seattle. IPD was used in coordinating the design and building of energy efficient energy systems, sustainable materials and water conservation technology. Through the participation of all stakeholders from the earliest stages of estimation, the project team could accurately estimate the costs and savings, allowing the building to meet its sustainability goals at the cost only [21].

The Bullitt Center is designed to be a net zero energy building, with the help of solar panels, geothermal and electric batteries.

Bullitt Center, Seattle

The Bullitt Center in Seattle is one outstanding best example of a green building project, and facilitated Integrated Project Delivery (IPD). The building is known around the world as the 'greenest commercial building in the world' because of its net zero energy design and its commitment to sustainability. IPD was instrumental in coordinating the installation of energy efficient systems, construction with sustainable materials and advanced technologies for water conservation institutionally so that all parties involved in decision making — architects, engineers, contractors and sustainability experts — were from the start.

But of all the things that make the Bullitt Center stand out, the thing that has really impressed me is its net zero energy design, a feat achieved with the use of, among other things, on site solar panels and geothermal heating and cooling systems. And the building utilises a rainwater harvesting system and composting toilet system, creating a smaller carbon footprint than most buildings. However, prediction of these sustainable features over time and their integration into the project's budget was very dependent on an extensive energy modeling and Life Cycle Assessment (LCA) [22].

The Bullitt Center is a symbol of how IPD can mitigate the inherent risks of sustainable building with cooperation between all parties. Early involvement of estimators and sustainability consultants allowed the project to meet ambitious sustainability targets on budget. The Bullitt Center's success indicates that green building practices can be viable in commercial construction and that early integration of sustainability goals into a estimating process is critical.

PNC Tower, Pittsburgh

The other case study which demonstrates the successful green building estimation process is the PNC Tower in Pittsburgh, which was to be one of the greenest skyscrapers in the world. The plan called for LEED Platinum certification by the U.S. Green Building Council, the highest award the council makes. Balancing the high upfront cost of sustainable materials and the advanced energy systems with their long term savings, estimators for the PNC Tower faced this challenge.

Not only does the building use several innovative energy saving systems, including a double skin façade that allows for natural ventilation to reduce the building's cooling load, there are also other manoeuvres carried out intended to minimize the building's demands upon the grid. A green roof was installed to manage stormwater and reduce heat island effects, high efficiency LED lighting and smart building controls were employed to minimize energy consumption. LCA was used to quantify the environmental benefits of these features so the project team could justify the higher upfront costs [23].

Energy modeling was crucial in the case of PNC Tower, where Pittsburgh's variable weather cannot be assumed; and prediction of building performance under different climatic conditions was requested. The building's energy use was modeled with advanced tools to predict long-term savings which were incorporated into the project's financial estimates. Delivery of a high performance sustainable building within budget requires the successful completion of PNC Tower, featuring sophisticated estimation methodologies such as energy modeling and LCA.

Conclusion

There are many challenges for estimating the cost of sustainable construction, from accounting for higher starting costs of green materials to predicting long term, energy savings and environmental benefits with an accuracy. But these issues can be overcome with the help of advance methods as Life Cycle Assessment (LCA), Integrated Project Delivery (IPD) and energy modeling. Integrating sustainability from the outset in the estimation process will enable project teams to find that green building practices can be environmentally responsible and financially viable.

The construction industry has started to embrace sustainability and this will be crucial for developing more sophisticated estimation tools and collaborative project management. Furthermore, estimation practices will continue to be shaped by green building certifications like LEED and BREEAM which provide very specific ways of quantifying costs and benefits of sustainable construction.

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