Hindawi Publishing Corporation
ISRN Construction Engineering
Volume 2013, Article ID 656742, 10 pages
http://dx.doi.org/10.1155/2013/656742

*Research Article*

# A Framework to Reconcile Green Goals with Budget Reality

**Rachel Mosier[1] and Douglas D. Gransberg[2]**

[1] *College of Engineering, University of Oklahoma, 202 W. Boyd Street, Room 107, Norman, OK 73019-0631, USA*
[2] *Iowa State University, 494 Town Engineering Building, Ames, IA 50011-3232, USA*

Correspondence should be addressed to Douglas D. Gransberg; dgran@iastate.edu

Received 31 March 2013; Accepted 23 April 2013

Academic Editors: T. Bilir, S. P. Low, and V. Yepes



A public agency that decides to implement green design and construction features in its capital improvement program is actually adding an undetermined incremental cost to the initial cost of public buildings. Past research has portrayed these costs as a percentage increase, essentially creating an overall contingency for green buildings, but no work has been done to quantify the incremental cost on a building's actual design program that can be assigned directly to the project budget. This research sought to provide an objective approach to estimating sustainable design and proposes a framework for estimating the initial capital costs of sustainable building design and construction as measured by the Leadership in Energy and Environmental Design (LEED) certification program. The framework allows tracking of costs during design and can be utilized for estimating future projects. The framework is developed using case study analysis of green building projects in OK City, Oklahoma. The paper concludes that the cost of "going green" can be estimated as a unit price basis as a cost per LEED credit. The proposed framework can be used by any public agency to determine the additional cost of LEED certification and for budgeting future projects.

## 1. Introduction

To design and build public buildings that are more sustainable and have less impact on the environment often adds a marginal additional first cost that public agencies have been hesitant to pay. In municipal capital improvement programs, the aversion to increased cost was exacerbated by the fact that funding often is obtained by selling bonds to cover the design and costs of the project and it is difficult to determine exactly how much additional cost must be add to historical costs to ensure that sufficient funding is obtained in a given project's bond sale [1]. Green Building proponents such as the US Green Building Council (USGBC) justify the increase in design and construction costs financially by citing offsetting savings in life cycle costs from the green building's reduced energy and utility consumption. The consideration of life cycle costs is typically done during the design phase as a part of a value engineering effort [2], which occurs after the budget is fixed based on the completed municipal bond sale. However, the resulting increase in the construction cost to enhance sustainability could jeopardize project progress in one of two ways if the amount of available municipal bond funding does not cover the final as-designed cost of the constructed building First, the project may be delayed for re-design to bring its cost down to match available funding [3]. If that option is not possible, the public agency must go back to the taxpayers to obtain permission to sell additional bonds to cover the shortfall. Both cases put the project at further risk for cost increases due construction price escalation during the time it takes to either redesign or obtain additional funding [4].

As a result of the above discussion, it is clear that no matter how much the potential savings in future costs from sustainable design features may be, the bond-funded public building project manager must be able to accurately estimate the total cost of design and construction before the agency asks for permission to acquire the necessary funding and begins the bond sale process. A previous study by Molenaar et al. [5] termed the incremental additional cost of sustainable design as the "green premium." This paper presents a framework to satisfy this need for a green premium estimating tool. The applicability of the framework is demonstrated through case study analysis of green building projects recently constructed by the City of Oklahoma City (COKC), OK.

## 2. Background and Literature Review

To design and build buildings that are more sustainable and have less impact on the environment often adds a marginal first cost that owners have been hesitant to pay. The aversion to increased cost was exacerbated by traditional low bid project delivery where the emphasis, both in design and construction, is to reduce the capital cost of a facility to the lowest possible amount [3] Traditional project delivery is a linear process proceeding sequentially from design, to bid, then to build. Consequently delays often occur when cost estimate or bids come in too high and the project must be re-designed [6]. In a low bid project, the designer specifies the minimum acceptable level of quality, the construction contractor bids to furnish the minimum level of quality shown in the construction documents, and the owner inspects to make sure it got the minimum level of quality. Thus, quality was essentially minimized by the process by which a building was delivered. There is no incentive for the design and construction professionals go beyond the limits set in their contracts [7]. Any consideration of life cycle costs was typically done during the design phase as a part of a value engineering effort [8], with the aim of reducing the cost of the as-designed project to meet the restrictions of the budget [3]. Hence, to deliberately increase the construction cost to enhance sustainability could cause the project to be canceled [4].

The actual value of the green premium is a controversial topic with a variety of authors weighing in on both sides of the issue. A 2007 study by Langdon [9] that compared green and non-green buildings using the Australian Green Start rating system and concluded that a premium of 3% to 5% could be associated with green buildings construction costs. Rawlinson [10] found that green office buildings accrued a green premium of 6%. Fowler and Rauch [11] essentially concurred with the two previous studies finding that the premium ranged from as little as 1% to as much as 8%. Tatari and Kucukvar [12] asserted that "high performance sustainable building projects required higher capital investment and the required capital was proportional to the intended building overall LEED-NC rating." On the other side of the argument, Kats [13], Nilson [14], Stegall [15] and the Packard Foundation [16] all cited green premiums of less than 3% for a variety of project types.

The increased awareness of the impact of buildings on the environment and the need to conserve resources during construction and subsequent occupancy provided the foundation in the development of guidelines for sustainable design and construction. The advent of the USGBC and subsequent introduction of the Leadership in Energy and Environmental Design (LEED) rating system in 1998 created broad market acceptance for the first time [17]. The USGBC's LEED rating system furnishes a benchmark and measuring tool for designers, builders, and owners to measure the inherent sustainability of a building. The result is a series of rated levels of certification: "Certified," "Silver," "Gold," and "Platinum." The certification level of a given building is based on the total points that assigned to each specific category [18]. LEED ratings and credits provide a simple way for owners to articulate their needs for sustainability in a building project [19]. Hence it provides a convenient and well-accepted benchmark from which to calculate the green premium.

The citizens of the US have grown more environmentally aware and this created a demand for city governments to set an example by constructing public buildings that not only saved energy through direct reduction in consumption but also leverage the design and construction process to reduce the facilities overall impact on the environment as a whole [20]. In 2009, the COKC established an Office of Sustainability and formally implemented sustainable design and construction methods in capital improvement projects. Two initial projects were identified with the USGBC LEED certification program [18] as the sustainability benchmark for future public building projects. To effectively implement its sustainable building policy, COKC needed to develop a reliable method is needed to estimate the green premium and ensure adequate funding is obtained for completion without delay to these projects.

As is common throughout the US, the COKC obtains its funding for new construction projects comes from capital improvement funds obtained through the sale of municipal bonds, and therefore, must ensure that funding sufficient to cover any additional costs for a green public building before project design can begin [21]. While future life cycle savings can be used to justify the need higher initial capital costs, COKC still obtain sufficient initial funding to incorporate green design and construction features in a given project.

*2.1. Case Study Methodology.* A methodology for quantifying incremental initial costs due to sustainable design issues affecting the owner is required in order to develop a framework for planning a sustainable building project. A comparative analysis of the case study project credit costs is performed. The framework highlights the budget constraints of a LEED project, specifically the cost of LEED credits to achieve certification. Costs are isolated for estimating future LEED costs on a public agency's capital improvement budget. Budgetary constraints and design choices may be required to resolve constraints found through use of the framework.

The increased awareness of the impact of buildings on the environment and the need to conserve resources during construction and subsequent occupancy provided the foundation in the development of guidelines for sustainable design and construction. The advent of the USGBC and subsequent introduction of the LEED rating system in 1998 created broad market acceptance for the first time [17]. The USGBC's LEED rating system furnishes a benchmark and measuring tool for designers, builders, and owners to measure the inherent sustainability of a building. The result is a series of rated levels of certification: "Certified," "Silver," "Gold," and "Platinum." The certification level of a given building is based on the total points that assigned to each specific category [18].

Table 1: LEED credits with types of costs [22].

| Category | Credit | Contractor impact |
|---|---|---|
| Sustainable sites | Brownfield redevelopment | Moderate |
| Water efficiency | Water efficient landscaping | Some |
| Energy and atmosphere | Enhanced commissioning | Major |
| Materials and resources | Construction waste management | Major |
| Indoor environmental quality | Minimum indoor air quality (IAQ) performance | Some |
| Innovation and design | LEED accredited professional | Moderate |

*2.2. Costs of LEED Certification.* The costs of achieving LEED certification can be separated into two categories: the administrative costs to obtain certification from USGBC and those associated with an increase in cost sustainable design features [23]. Contrary to claims LEED certification comes at no increase in cost [4, 23]; the minimum an owner must pay is the $3500 registration fee to apply for LEED certification [24]. For the case study projects, COKC paid an administrative fee of 0.5%–1% of estimated construction costs to the designers [9]. In public projects, all of these LEED costs become public record and part of the dialog about how the government is spending the public's monies. Although these costs vary, they can be "in the range of $30,000–$60,000" [25].

*2.3. The LEED Checklist and Rating System.* The LEED checklist provides a standard scale to measure the use of materials, systems and design innovation, and is broken into 6 categories.

(1) Sustainable Sites.

(2) Water Efficiency.

(3) Energy and Atmosphere.

(4) Materials and Resources.

(5) Indoor Environmental Quality, and

(6) Innovation and Design.

With the exception of Innovation & Design, each section has specific requirements to achieve credits for products and methods [18]. Syal et al. [22] further classified the credits as to their impact on contractors. Table 1 shows an illustrative example of typical credits in each category as well as Syal's impact factor.

*2.4. LEED Construction Method.* This research focuses on DBB project delivery, the most traditional delivery method. Molenaar et al. [5] investigated the state of the practice for different project delivery methods in sustainable buildings to determine the effectiveness of project delivery method on an owner's ability to realize its sustainability objectives. Molenaar et al. defined a point in the procurement process where achieving a given LEED certification level became a contract requirement, the "green guarantee is defined as the contractual responsibility to deliver a building that will receive the owner's designated level of LEED certification" [5].

It can be argued that lowest bid price does not equal lowest final cost when using traditional project delivery [3, 26]. State statutes often require public agencies to use DBB for their capital investment programs. The major constraint of traditional project delivery is that many LEED credits like the Construction Indoor Air Quality credit require the contractor's participation to achieve, thus it is critical to communicate these requirements in construction documents. COKC required the contractor to provide their own LEED AP as part of the contract to improve the probability of success.

*2.5. LEED Building Construction Cost.* Decisions for credits may include reuse and recycling materials. These individual sustainable costs must be identified prior to the bid submission. The contractor must then determine the associated credit costs and provide documentation of recycling and the construction IAQ management plan. "Fundamental Commissioning of the Building Energy Systems" is already incorporated into a typical construction budget since it is required by COKC building code [27]. A project's location affects minimum building code required credits, and must be in the construction budget for the project to receive a building permit, so it would not be considered an additional cost to earn this credit.

The focus of a public project has to not only includes the costs paid by appropriated funds, but needs to address the benefits that will be realized. Public buildings count on the public for both construction financing and operation and maintenance funding. Public opinion demands that the costs be justified by tangible benefits such as energy savings over the building's life. Requiring energy design enhances operation and maintenance cost savings and is a staple in a sustainable design program [28].

*2.6. Previous Attempts to Determine LEED Project Cost.* Previously Langdon [9] determined the difference in total capital costs while demonstrating a percentage increase per point. The US General Services Administration studied individual credit costs from the perspective of no cost, low cost, moderate cost and high cost premiums [11]. The City of Portland, Oregon, has also commissioned a study [29], using existing buildings that were not LEED certified, and extrapolated the additional costs to make these projects comply with LEED certification requirements. These studies were specific in nature and their methodology could not be used for other locations.

*2.7. Sustainable Design Cost Benefits.* Because acceptance of credits is not guaranteed, designers often plan for more credits than the minimum required to achieve the owner's desired level of LEED certification and unintentionally create cost growth. In DBB projects, the contractor is the last participant to join the project team and does not participate in credits options. The contractor may not actualize the designer's assumptions for credits like local materials, recycled waste, or LEED-certified project personnel if those products and services are not available in the project area. The designer may focus on less expensive, easily achievable credits without the long-term benefits of other potential credits [23]. An example of such a low-cost credit would be providing a shower stall and bicycle racks to encourage cycling to the building.

A public agency must justify increases in capital budget by future savings in the post-construction operating budget. Most public agencies receive their capital funding on an as-needed basis from sources without benefits of the operating budget [1]. With general obligation bonds, the voting public authorizes the costs but the budget cannot exceed the voter authorized ceiling. It is therefore critical to understand the value of the "green premium" before the design and construction budget is fixed, and make the case for life cycle savings before the project's program is constrained by the realities of public funding.

## 3. Methodology

The purpose of this research is to develop a systematic, repeatable approach to quantify costs due to sustainable design as a foundation for project planning using the COKC green building experience. Two primary research instruments are used: a comprehensive literature review and case studies of actual COKC green building projects. The information gleaned from the case studies is coupled with information collected in the literature review to validate the conclusions. The two case study projects, a library and a fire station, were selected for the following reasons.

(i) Both were designed as LEED projects from the initial phase.

(ii) Each represents a type of project where COKC has not only built non-LEED certified facilities, but also has a programmed need to build future facilities.

(iii) All the cost data was readily available for both LEED and non-LEED projects of the same type.

In both projects, it is critical to the COKC analysis to establish the LEED credit baseline so that features that are included to meet the building code are not included in the calculation of additional costs of sustainability. For purposes of analysis and to quantify the actual additional construction costs, it was assumed that case study buildings would seek the minimum LEED certification of "Certified". To conduct the analysis for a higher level could require comparing a much larger variation in credits.

*3.1. Case Study Locality.* The location of a building project affects the ability to achieve LEED Certification. Five credits in COKC are achieved merely by complying with minimum building code requirements. In many areas of the country, the local building code requirements account for even more credits and those would be required to obtain a building permit regardless of the owner's sustainability goals [5]. For projects in COKC the code requirements include the following LEED credits.

(i) SS Prereq1, Construction Activity and Pollution Prevention, is required to reduce loss of topsoil and increased run-off.

(ii) EA Prereq2, Minimum Energy Performance, is required by code.

(iii) EA Prereq3, Fundamental Refrigerant Management, is the current industry standard.

(iv) EA EQ Prereq1, Minimum IAQ Performance, is required by code.

(v) SS6.2, Storm Water Design—Quantity Control is also required by code to decrease storm water run-off.

*3.2. LEED Credit Cost Metrics.* A decision-making framework is required to help owners determine the cost of implementing sustainable design and seeking LEED certification. The LEED rating system is a nationally recognized metric for measuring sustainability in building projects [30]. The LEED checklist provides a numerical value in credits for each sustainable design and construction alternative. Having an objective methodology to measure potential sustainability is essential to optimizing the owner's sustainability goals within budget [21].

To create a structure for funding-based decision-making, the LEED credits are separated into three cost categories.

(1) Hard cost credits,

(2) Soft cost credits and,

(3) Non-cost credits.

Hard cost credits are quantifiable with construction cost and maintenance savings such as reduced energy bills. Soft cost credits are quantifiable with construction cost, but not quantifiable through a tangible change in the building's operation and maintenance costs. These costs also fall within the "feel-good" factor [31]. Non-cost credits are incidental to the project and are usually somewhat random in nature. Classification into these three categories is based on the LEED credit descriptions themselves, which include information about initial and potential costs, as well as the environmental and economic issues that make the credit worth consideration [30]. Based on these descriptions, each credit has been assigned to a cost category for discussion in this research as shown in Table 2. One can see that there are fewer quantifiable hard cost credits, than soft cost credits, and non-cost credits. This is significant because with only 18 hard cost credits of 26 minimum credits for LEED Certified, this means that every project will require credits that are not justifiable by initial cost alone. The decision-making framework assists the owner in choosing societal or environmental impacts

Table 2: LEED credit cost categories.

| | | |
|---|---|---|
| | Hard | |
| EA-1 Optimize Energy Performance | MR-1.1 Building Reuse—maintain 75% of existing structure | SS-PR1 Construction Activity and Pollution Prevention |
| EA-2 On-site renewable Energy | MR-1.2 Building Reuse—maintain 95% of existing structure | WE-1.1 Water Efficient Landscaping—reduce by 50% |
| EA-PR1 Commissioning of Building Energy Systems | MR-1.3 Building Reuse—maintain 50% of interior non-structural | WE-1.2 Water Efficient Landscaping—no potable water use or no irrigation |
| EA-PR2 Minimum Energy Performance | SS-6.1 Storm Water Design—Quantity Control | WE-2 Innovative Wastewater Technologies |
| EQ-6.1 Controllability of Systems—lighting | SS-6.2 Storm Water Design—Quality Control | WE-3.1 Water Use Reduction—20% Reduction |
| EQ-8.1 Daylight and Views—daylight 75% of spaces | SS-8 Light Pollution Effect | WE-3.2 Water Use Reduction—30% Reduction |
| | Soft | |
| EA-5 Measurement and Verification | MR-4.1 Recycled Content—10% | SS-4.1 Alt. Trans.—Public Transportation Access |
| EA-6 Green Power | MR-4.2 Recycled Content—20% | SS-4.2 Alt. Trans.—Bicycle Storage and Changing Rooms |
| EA-PR3 Fundamental Refrigerant Management | MR-5.1 Regional Materials—10% | SS-4.3 Alt. Trans.—Low Emitting and Fuel Efficient Vehicles |
| MR-2.1 Construction Waste Management—divert 50% | MR-5.2 Regional Materials—20% | SS-4.4 Alt. Trans.—Parking Capacity |
| MR-2.2 Construction Waste Management—divert 75% | MR-6 Rapidly Renewable Materials | SS-7.1 Heat Island Effect—Non-roof |
| MR-3.1 Materials Reuse—5% | MR-7 Certified Wood | SS-7.2 Heat Island Effect—Roof |
| MR-3.2 Materials Reuse—10% | MR-PR1 Storage and Collection of Recyclables | |
| | Non-Cost | |
| EA-3 Enhanced Commissioning | EQ-4.3 Low-Emitting Materials—Carpet Systems | EQ-PR2 Environmental Tobacco Smoke Control |
| EA-4 Enhanced Refrigerant Management | EQ-4.4 Low-Emitting Materials—Composite Wood and Agrifiber Products | SS-1 Site Selection |
| EQ-1 Outdoor Air Delivery Monitoring | EQ-5 Indoor Chemical and Pollutant Source Control | SS-2 Development Density and Community Connectivity |
| EQ-2 Increased Ventilation | EQ-6.2 Controllability of Systems—Thermal Comfort | SS-3 Brownfield Redevelopment |
| EQ-3.1 Construction IAQ Plan—during construction | EQ-7.1 Thermal Comfort—Design | SS-5.1 Site Development—Protect or Restore Habitat |
| EQ-3.2 Construction IAQ Plan—before occupancy | EQ-7.2 Thermal Comfort—Verification | SS-5.2 Site Development—Maximize Open Space |
| EQ-4.1 Low-Emitting—Adhesives and Sealants | EQ-8.2 Daylight and Views—views for 90% of spaces | ID-1 Innovation in Design |
| EQ-4.2 Low-Emitting—Paints and Coatings | EQ-PR1 Minimum IAQ Performance | ID-2 LEED Accredited Professional |

while weighing budget requirements. Table 1 focuses on the cost and environmental or societal impacts of LEED credits.

An example of a LEED credit with hard costs is MR1 Building Reuse. Costs due to reusing an existing building are clearly identifiable. Savings due to reusing a building are also quantifiable. The difference in the two is defined as the hard cost. An example of soft costs is the signage for hybrid vehicle parking. Although there is a quantifiable initial cost, the savings are accrued indirectly by society and not directly attributable to the project itself. This study calls the difference between the design and construction costs and the societal benefit the soft cost. An example of a non-cost credit would be the ability to build on a contaminated site. Previously developed land may have expenses due to remediating contaminated sites or purchasing in a densely populated area. Although these credits are difficult to quantify, they are generally accepted to have a societal return. However, a public entity has an obligation to build a project with the least initial construction cost [32], so unidentifiable benefits are difficult to use as a basis for an owner's decision alone. Finally, if a credit, such as Site Selection could potentially be categorized in more than one category, but that categorization

Table 3: Case studies.

| Project | Cost | Size | Location | Major environmental features |
|---|---|---|---|---|
| Library | $8,094,819 | 35,247 sf | NW OKC | Geothermal Heating, Daylight Harvesting |
| Fire station | $2,766,035 | 14,580 sf | Bricktown | Brownfield Redevelopment, Recycle Existing Building Materials |

is dependent on the conditions associated with a specific project, it was placed in the category that would apply without the need to qualify the choice given an individual project's scope of work.

## 4. Case Study Analysis

Integrating the details of the case study projects with the cost categories described above is essential to the framework. The case studies are described in Table 3.

The two case studies include actual LEED costs and the credits initially sought during the design process to achieve LEED certification. The consultant provided initial cost preliminary estimates, which reflect costs added by the LEED requirements that would not have been a construction cost otherwise. Basic project information, LEED credits, and construction costs are tabulated and include total construction cost and the square footage of the building. A large range of credit costs is found from $240,000 for geothermal heat pumps at the Library to $100 for Tobacco Smoke Signage at the Fire Station. For budgeting purposes all of the credit costs must be simplified into a usable budgeting metric. From this information a cost per LEED credit per square foot is determined.

*4.1. Case Study Library.* The Library project sought to achieve the following credits shown in Table 4. The table separates the credits into the above-defined cost categories: hard, soft, or non-cost credits, noted with H, S, or N. The cost/savings associated with each credit where it could be quantified is also shown in the table.

Like Table 2, there are fewer hard cost credits with 10, followed by soft cost credits with 11, then non-cost credits with 20. There are 35 credits shown plus 7 prerequisites. Since the prerequisites have dollars associated with them, the costs are quantified. The costs associated with the credits are illustrated to show where the LEED investment is spent.

Figure 1 shows the distribution of cost for each of the cost categories. For the library, geothermal heating is desired. Although the Hard Cost credits are the least amount of overall credits in the Library, they still cost the most to the owner. The Non-Cost credits represents the largest portion of credits sought, but had the least cost. The distribution of dollars is the inverse of the credits with the largest portion of the LEED budget being spent on the least amount of credits. In this case, the Hard Cost credits are also the credits with a tangible return on investment.

*4.2. Case Study Fire Station.* The Fire Station project sought to achieve the credits shown in Table 5 during construction. For the Fire Station, the number of quantifiable hard cost

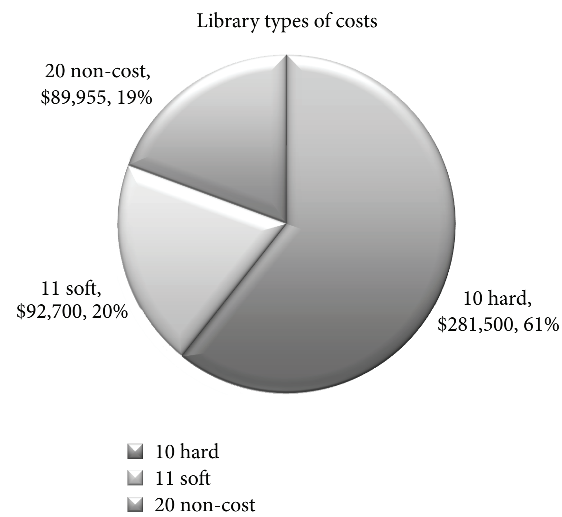



Figure 1: LEED Credit Cost Breakdown for the Library Project.

credits is 10, followed by non-cost credits with 13, then soft costs with 14. In the case of the Fire Station, Optimize Energy Performance is the most expensive item. Again the Hard Cost credits are the least in number, but still cost the most to the owner. The Soft Cost credits represent the largest portion of credits sought, but cost the least.

The cost distribution is illustrated in Figure 2. With the Fire Station, like the Library, the most budget is spent on the least amount of credits.

## 5. Framework Analysis

The LEED credits costs provide the foundation for the framework to be used as a decision tool. The framework quantifies the additional cost associated with achieving LEED credits during the development phase of capital project budget determinations. The case study data in the framework is formatted to determine sustainable design and construction specific to COKC's market at project conception. The framework is populated with LEED credit cost data and tabulated using USGBC's LEED credit checklist. At this stage the owner will be budgeting future capital improvement dollars without the benefit of having a designer under contract [33]. The project design constraints must be identified for future capital improvement project budgets.

*5.1. The Proposed Framework.* The flowchart in Figure 3 directs the owner through a series of questions guiding the owner through the decision-making process. The owner is assisted with design assumptions and sustainable design

Table 4: Library LEED credits with types of costs.

| | Cost | Type |
|---|---|---|
| SS | | |
| Prereq 1 | $— | H |
| Credit 2 | $— | N |
| Credit 4.2 | $4,800 | S |
| Credit 4.3 | $1,600 | S |
| Credit 5.2 | $— | N |
| Credit 6.1 | $15,000 | H |
| Credit 7.1 | $15,000 | S |
| Credit 7.2 | $— | S |
| Credit 8 | $— | H |
| WE | | |
| Credit 1.1 | $20,000 | H |
| Credit 3.1 | $5,500 | H |
| Credit 3.2 | $— | H |
| EA | | |
| Prereq 1 | $30,000 | S |
| Prereq 2 | $— | H |
| Prereq 3 | $— | H |
| Credit 1 | $240,000 | H |
| Credit 3 | $— | N |
| Credit 4 | $— | N |
| MR | | |
| Prereq 1 | $1,500 | S |
| Credit 2.1 | $12,000 | S |
| Credit 4.1 | $12,000 | S |
| Credit 4.2 | $— | S |
| Credit 5.1 | $— | S |
| Credit 7 | $15,800 | S |
| ID | | |
| Credit 1.1 | $— | N |
| Credit 2 | $42,000 | N |
| EQ | | |
| Prereq 1 | $— | N |
| Prereq 2 | $200 | N |
| Credit 1 | $8,000 | N |
| Credit 3.1 | $3,000 | N |
| Credit 3.2 | $1,000 | N |
| Credit 4.1 | $10,750 | N |
| Credit 4.2 | $— | N |
| Credit 4.3 | $— | N |
| Credit 4.4 | $— | N |
| Credit 5 | $— | N |
| Credit 6.1 | $1,000 | H |
| Credit 6.2 | $22,000 | N |
| Credit 7.1 | $4,000 | N |
| Credit 7.2 | $5,000 | N |
| Credit 8.1 | $— | N |
| LEED Fees | $4,005 | |
| Net Cost | $464,155 | |

SS: Sustainable Sites; WE: Water Efficiency; EA: Energy and Atmosphere; MR: Materials and Resources; EQ: Indoor Environmental Quality; ID: Innovation and Design; H: hard cost credit; S: soft cost credit; N: Non-cost credit.

Table 5: Fire Station LEED credits with types of costs.

| | Cost | Type |
|---|---|---|
| SS | | |
| Prereq 1 | $— | H |
| Credit 1 | $— | N |
| Credit 2 | $— | N |
| Credit 3 | $— | N |
| Credit 4.1 | $— | S |
| Credit 4.2 | $300 | S |
| Credit 4.3 | $300 | S |
| Credit 4.4 | $— | S |
| Credit 6.1 | $— | H |
| Credit 7.1 | $— | S |
| Credit 7.2 | $— | S |
| Credit 8 | $3,500 | H |
| WE | | |
| Credit 1.1 | $4,000 | H |
| Credit 3.1 | $4,500 | H |
| Credit 3.2 | $— | H |
| EA | | |
| Prereq 1 | $11,000 | H |
| Prereq 2 | $6,000 | H |
| Prereq 3 | $— | S |
| Credit 1 | $25,000 | H |
| MR | | |
| Prereq 1 | $350 | S |
| Credit 2.1 | $— | S |
| Credit 2.2 | $— | S |
| Credit 4.1 | $— | S |
| Credit 4.2 | $8,000 | S |
| Credit 5.1 | $— | S |
| Credit 7 | $6,200 | S |
| EQ | | |
| Prereq 1 | $— | N |
| Prereq 2 | $100 | N |
| Credit 1 | $2,000 | N |
| Credit 3.1 | $— | N |
| Credit 3.2 | $1,000 | N |
| Credit 4.1 | $1,750 | N |
| Credit 4.2 | $— | N |
| Credit 5 | $1,750 | N |
| Credit 6.1 | $— | H |
| ID | | |
| Credit 1.1 | $— | N |
| Credit 2 | $13,845 | N |
| LEED Fees | $3,950 | |
| Total | $12,600 | |

SS: Sustainable Sites; WE: Water Efficiency; EA: Energy and Atmosphere; MR: Materials and Resources; EQ: Indoor Environmental Quality; ID: Innovation and Design; H: hard cost credit; S: soft cost credit; N: non-cost credit.

decisions necessary to determine the costs associated with seeking LEED certification.

The framework defines technical requirements, green policy requirements and cost. Technical requirements include building square footage, lot size, and so forth. The green policy requirements include the USGBC LEED credits, the Building Code and the Sustainable Policy. From the project scope, the initial budget is determined. The cost including the green premium must be less than or equal to the initial budget, otherwise the project cost must be re-evaluated. Additional funding must be available or the project scope must be changed to bring the project into budget including reducing the credits chosen.

Design constraints and requirements are checked against the initial project scope of work to verify that the green design will meet the criteria given. The designer must meet the codes and policies by changing a technical requirement like square

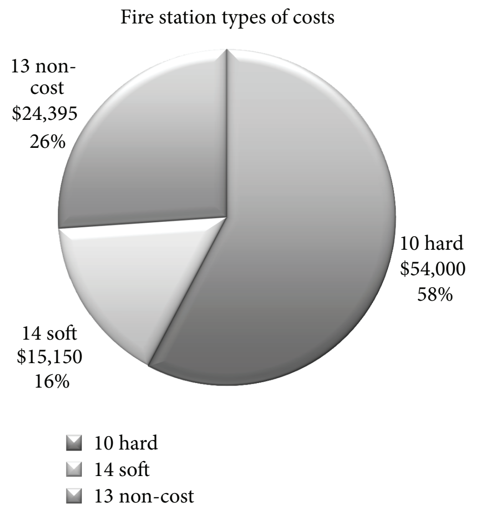



Figure 2: LEED Credit Cost Breakdown for the Fire Station Project.

footage, which will impact estimated cost so a review of all of the initial requirements is necessary. A sustainability level is determined based on all of the variables chosen. This level of LEED Certification will be compared to the original project requirements. If the required certification level is met, then the design can be completed and construction begins. If the sustainability level is not achieved, then the new data is entered into the framework.

The credits and cost categories must be reviewed. The credit choices are compared to the sustainable building policy. If the credits chosen are not within the project budget, reviewing justification of the assumed credits is appropriate. With the credits chosen, the estimated cost of a LEED certified project is checked against the initial project budget. The green premium is difference between the estimate and the initial budget. If the cost of a green building is too high, then all credits are reviewed a final time by rank ordering each credit and its associated cost. If possible, credits are selected to bring the project back into budget or the owner must perform a cost/technical tradeoff analysis [14]. Credits May have to be eliminated to meet the financial realities of the project so a final review must be performed of the project and its technical requirements for a final iteration.

*5.2. Using the Framework.* Although the owner reduces the number of credits to achieve, it does not mean the building is not sustainable. The proposed framework permits the public owner to maximize the project's sustainability within the constraints of available funding and the need to bring a facility on line by a specific date. Many public owners use the LEED credit checklist to measure the sustainability of their projects do not choose to seek formal LEED certification even when the required number of credits would support a given LEED level [5]. The real value of the proposed framework is to provide structure to the green decision-making process by furnishing a repeatable methodology that reconciles the desire to minimize environmental impact while adhering to the constraints associated with public funding.

Applying the approach shown in Figure 1 to a hypothetical construction project, the agency would first evaluate its current design criteria and construction practices to identify those that already promote sustainability. A common example would be the use of recycled asphalt pavement (RAP) in the public building's parking lot. If the agency has already implemented the practice by requiring a certain percentage of RAP in all pavements, the cost of the RAP should be assigned to the baseline not the green premium. However, if the agency decides to increase the percentage of RAP used in the given project over the current allowable percentage, the cost of the RAP above the existing standard should rightly be assigned to the green premium until such time that the agency changes its policy and/or specifications. The output of the evaluation is the consolidated list of baseline features of green design and construction. The next step is to evaluate the potential for adding sustainable features to the project and select the ones that are desired. The unit price for each green feature is then estimated and the cost of the baseline features is removed. The remaining features are then assessed knowing their costs and a value judgment is made as to which ones will be included in the preliminary design. Once preliminary design is completed, the agency's estimate for the green premium is made based on the quantities associated with each green feature. After the estimate for entire project, including the green features, is completed and compared with the budget. If the project is within budget, it can proceed with the selected suite of sustainable design and construction elements. If not, a reevaluation of the additional green features must be made and the green premium estimating process will be conducted until the scope of work matches the budget.

One advantage to the proposed process is that it segregates the required features of work from the discretionary ones. If the sustainability goals for the project cannot be met within the existing budget, the agency has the information necessary to request additional funding and justification for the costs of achieving those goals [34].

## 6. Conclusions

There are two important findings that can be drawn from the previous analysis. First, enhancing the sustainability of public building projects requires additional capital improvement funding. The COKC case study projects demonstrated that the actual impact on projects costs can range from low to high based on both the project itself and the timing of the decision to deliver a more sustainable project that current design standards would produce. Secondly, it is important to segregate the discretionary features of sustainable design and construction from the current features that already are sustainable. The LEED certification process was used in this study as a convenient way to measure the sustainability of the COKC case study projects, but as was illustrated in the hypothetical example that accompanied Figure 3, the concepts for quantifying the cost of sustainable design and construction can be applied to any type of project in any mode of transportation.

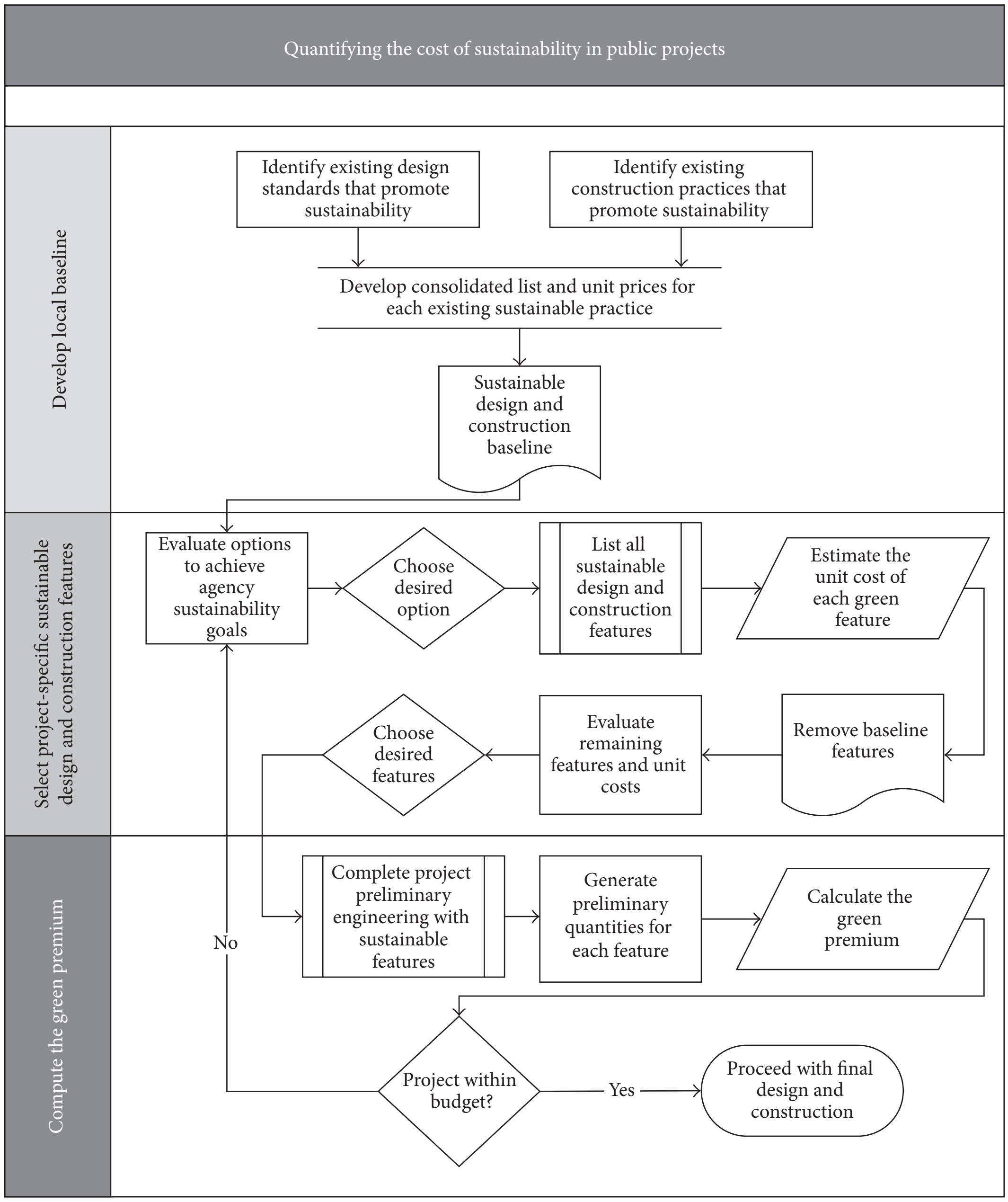



Figure 3: Proposed Framework for Computing the Green Premium.

The process of justifying sustainable design features in a public building must focus on only initial cost for determining the impact of including a LEED credit on the agency's ability to obtain the necessary funding to build the green building. While there is also a societal impact, it must be significant enough incentive to overcome additional capital costs. The study showed that LEED credits can be meaningfully be separated into three cost categories (hard, soft, and non-cost credits) to facilitate the analysis and help agency personnel better understand the actual costs associated with the green premium. The research used case studies validate the applicability of the proposed framework and demonstrate the ease with which it can be applied to any given project. The study also found that the cost of LEED credits required by code should not be included in the computation of the green premium. While the actual numerical results spring from cost data that only applies to COKC projects, the framework can be utilized for projects in any locality. This gives the user a projected budget for LEED Certification above and beyond the typical construction costs.

## References

[1] State of Oklahoma, *Indebtedness for Purchase, Construction or Repair of Public Utilities*, Article X, 27, Oklahoma Constitution, 1988.

[2] P. S. Dunston, J. F. McManus, and J. A. Gambatese, *Cost/Benefits of Constructability Reviews*, NCHRP, Washington, DC, USA, 2002, Project 20-7.

[3] M. A. Ellicott, "Best-value contracting," in *Proceedings, Area Engineers Conference, Transatlantic Division, U. S. Army Corps of Engineers*, Winchester, Virginia, 1994.

[4] A. R. Lapinski, M. J. Horman, and D. R. Riley, "Lean processes for sustainable project delivery," *Journal of Construction Engineering and Management*, vol. 132, no. 10, pp. 1083–1091, 2006.

[5] K. R. Molenaar, N. Sobin, D. D. Gransberg et al., *Sustainable, High Performance Projects and Project Delivery Methods: A state-of the practice Report*, White Paper, Charles Pankow Foundation, Ontario, Canada, 2009.

[6] B. J. Jackson, *Construction Management Jump Start*, John Wiley & Sons, Indianapolis, Indiana, 2004.

[7] M. Bresnen and N. Marshall, "Motivation, commitment and the use of incentives in partnerships and alliances," *Construction Management and Economics*, vol. 18, no. 5, pp. 587–598, 2000.

[8] P. S. Dunston, J. F. McManus, and J. A. Gambatese, *Cost/Benefits of Constructability Reviews*, TRB, Washington, DC, USA, 2002, NCHRP Project 20-7, Task 124.

[9] D. Langdon, *The Cost and Benefit of Achieving Green Buildings*, White Paper, Davis, Langdon & Seah International, Australia, 2007.

[10] S. Rawlinson, *Sustainability Offices*, Building Magazine Davis Langdon, 2007.

[11] K. M. Fowler and E. M. Rauch, *Assessing Green Building Performance: A Post-Occupancy Evaluation of 12 GSA Buildings*, Pacific Northwest National Laboratory, Seattle, Wash, USA, 2008, PNNL-17393.

[12] O. Tatari and M. Kucukvar, "Cost premium prediction of certified green buildings: a neural network approach," *Building and Environment*, vol. 46, no. 5, pp. 1081–1086, 2011.

[13] G. Kats, *Greening America's Schools: Costs and Benefits*, Capital E Research Report, 2006.

[14] M. L. Nilson, *Quantifying the cost impacts of LEED-NC gold construction in New York City [Senior Honors thesis]*, Lafayette College, Easton, Pa, USA, 2005.

[15] N. Stegall, *Cost Implications of LEED Silver Certification For New House Residence Hall at Carnegie Mellon University*, Carnegie Mellon University, Pittsburgh, Pa, USA, 2004, Senior Honors Research Project.

[16] Packard Foundation, Building for sustainability report: six scenarios for the David and Lucile Packard foundation, Los Altos.

[17] A. J. Hoffman and R. Henn, "Overcoming the social and psychological barriers to green building," *Organization and Environment*, vol. 21, no. 4, pp. 390–419, 2008.

[18] U. S. Green Building Council, *LEED For New Construction and Major Renovations V2.2*, 2005.

[19] D. R. Riley, B. E. Diller, and D. Kerr, "Effects of delivery systems on change order size and frequency in mechanical construction," *Journal of Construction Engineering and Management*, vol. 131, no. 9, pp. 953–962, 2005.

[20] S. Korkmaz, *Piloting evaluation metrics for high performance green building project delivery [Ph.D. dissertation]*, Pennsylvania State University, State College, Pennsylvania, USA, 2007.

[21] J. Smetanka, *CIties Pass Up Green Stamp of Approval, Say it Costs Too Much*, Star Tribune, Minneapolis, Minn, USA, 2011.

[22] M. G. Syal, S. Mago, and D. Moody, "Impact of LEED-NC credits on contractors," *Journal of Architectural Engineering*, vol. 13, no. 4, pp. 174–179, 2007.

[23] L. Matthiessen and P. Morris, *Costing Green: A Comprehensive Cost database and Budgeting Methodology*, Davis Langdon White Paper, 2004.

[24] Green Building Certification Institute, *LEED Project Registration and Certification Fees*, 2011.

[25] N. Howard and R. Watson, *Special LEED Section: An Update on LEED 2. 1*, Environmental Design and Construction, 2002.

[26] D. D. Gransberg, J. E. Koch, and K. R. Molenaar, *Preparing for Design-Build Projects: A Primer for Owners, Engineers, and Contractors*, ASCE Press, Reston, Va, USA, 2006.

[27] "Building Code," in *Code of Ordinances*, Chapter 12, Oklahoma City, Stillwater, Okla, USA, 2010.

[28] G. Augenbroe, A. R. Pearce, B. Guy, and C. J. Kibert, "Sustainable construction in the United States of America: a perspective to the year 2010," in *CIB-W82 Report*, pp. 1–32, Georgia Institute of Technology, Construction Research Center, 1998.

[29] Xenergy Inc. and SERA Architects, *Green City Buildings: Applying the LEED Rating System*, Portland Energy Office, Portland, Ore, USA, 2000.

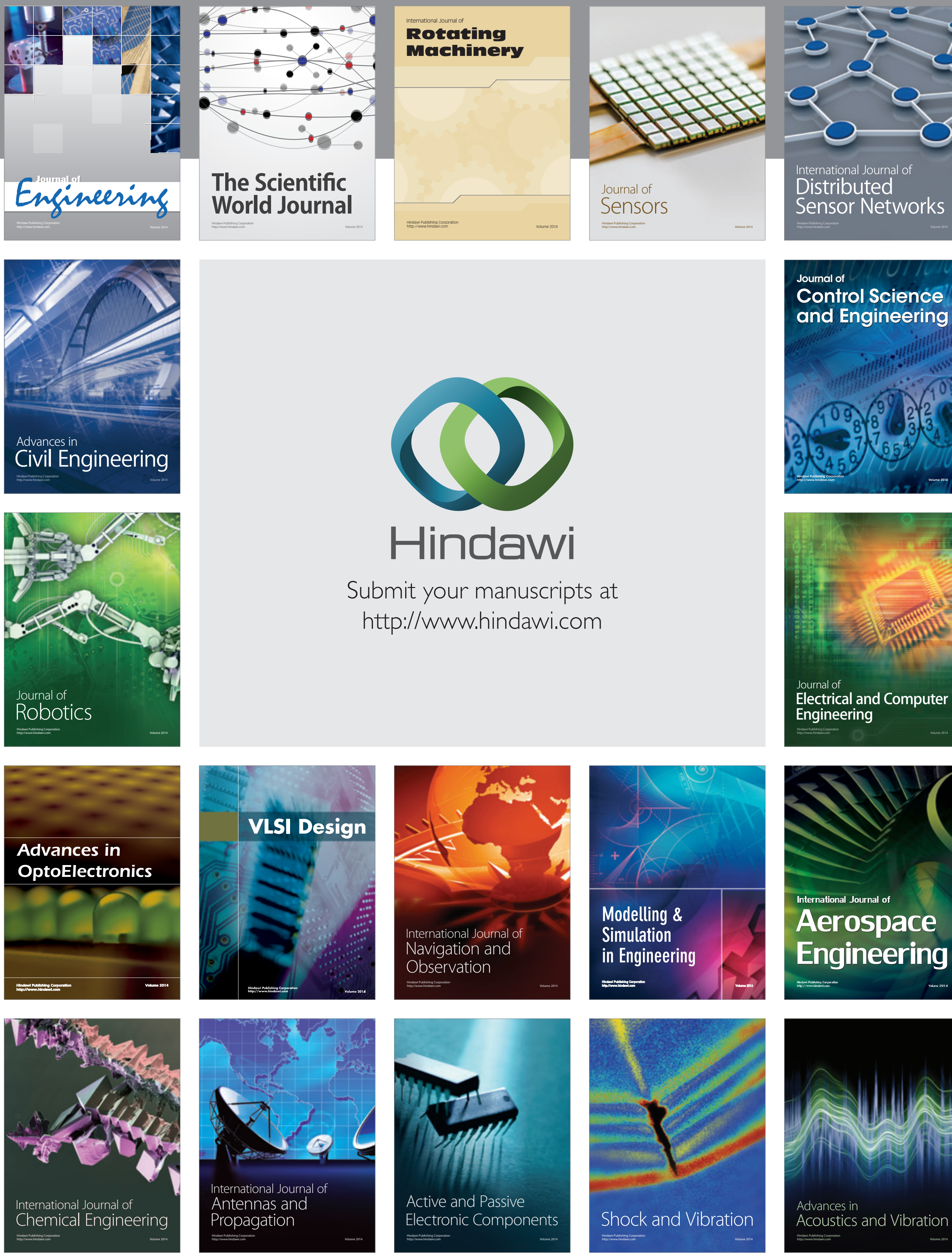
[30] U.S. Green Building Council, *Policy and Government Resources*, 2011.

[31] A. Nalewaik and V. Venters, "Cost benefits of building green," *Cost Engineering*, vol. 51, no. 1, pp. 28–34, 2009.

[32] Oklahoma Public Competitive Bidding Act, 61 Oklahoma Statutes, 101 et seq., 1974.

[33] D. D. Gransberg and E. Windel, "Communicating design quality requirements for public sector design/build projects," *Journal of Management in Engineering*, vol. 24, no. 2, pp. 105–110, 2008.

[34] D. D. Gransberg, "A framework for performance-based contractor prequalification," *Transportation Research Record*, vol. 2151, pp. 46–54, 2010.


Journal of Engineering
The Scientific World Journal
International Journal of Rotating Machinery
Journal of Sensors
International Journal of Distributed Sensor Networks
Advances in Civil Engineering
Hindawi
Submit your manuscripts at
http://www.hindawi.com
Journal of Control Science and Engineering
Journal of Robotics
Journal of Electrical and Computer Engineering
Advances in OptoElectronics
VLSI Design
International Journal of Navigation and Observation
Modelling & Simulation in Engineering
International Journal of Aerospace Engineering
International Journal of Chemical Engineering
International Journal of Antennas and Propagation
Active and Passive Electronic Components
Shock and Vibration
Advances in Acoustics and Vibration