Analysis of the Maximization of LEED Points for the Construction of a Mid-Rise Apartment Complex

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Introduction and Background

Currently, the leading method of green building certification is the Leadership in Energy and Environmental Design (LEED) rating system. The LEED system was developed by the U.S. Green Building Council (USGBC) in 1998 as "a consensus-based, market-driven building rating system designed to accelerate the adoption of green building practices" by creating widely accepted and regimented performance criteria. The main aim of the LEED certification process is to promote design and construction habits that increase profitability; improve occupant health and well-being; and reduce the negative environmental impacts of building site selection, energy and material usage, and environmental air quality (USGBC 2010a).

A total of eight LEED Rating Systems exist, covering almost all building and construction types. The most commonly implemented system is LEED for New Construction (LEED NC), which serves as the basis for this analysis. LEED NC "addresses design and construction activities" for both new commercial, institutional and residential buildings, as well as major renovations of these existing buildings (GBCI 2010). The LEED NC program awards credits on a 100-point scale and ensures that buildings are strategically designed to improve performance across the following categories:

- Sustainable sites (SS)
- Water efficiency (WE)
- Energy and atmosphere (EA)
- Materials and resources (MR)
- Indoor environmental quality (EQ)

Eight prerequisites must be satisfied to qualify for a LEED certification, and a possible ten bonus points can be achieved through innovation in design and regional priority credits (USGBC 2010b). An individual credit can earn multiple points, and not every credit is applicable to each project.

LEED projects can earn a Certified, Silver, Gold, or Platinum distinction depending on the number of sustainable attributes implemented (Table 1). Although the structure for earning points is relatively simple to comprehend, achieving a desired number of points requires creativity, integration, and analysis. This is especially true of the Gold and Platinum distinctions, which require significant effort and ingenuity from project designers to push the boundaries of sustainable building design and lead market transformation (Matthiessen and Morris 2004).

Levels	Points
Certified	40-49
Silver	50-59
Gold	60-79
Platinum	80+

Table 1: LEED for New Construction Rating Points System

Proponents of the LEED framework note that the system is straightforward, delivers a market-respected metric, and appeals to human nature (Cassidy 2003). These qualities have led to the widespread adoption of LEED as the industry standard. To further simplify sustainable construction, the USGBC offers extensive LEED training programs, an Accredited Professional exam, templates, and technical support. The system permits flexibility in the design options used to achieve each credit, employs regional credits to adapt to site-specific needs, and values the fact that various building types require particular rating systems. The underlying theory behind the LEED system is that architects, engineers, and developers are expected to adopt a more adaptive approach to building design.

While the LEED system encourages holistic design and represents an evolution of systems thinking concepts, detractors note that the philosophy does not always translate to practice. At present, the LEED rating system is undergoing its third revision. This indicates both adaptability towards trends in technology use and potential system flaws. For example, credit weighting is new to the latest revision and is an attempt to rebalance credits and ensure Energy & Atmosphere (EA) credits are pursued. Evidence that highly sustainable measures, many of which are encapsulated in the EA credits, are not often pursued uncovers an unfortunate mismatch. Behavioral and implementation issues surrounding the efforts of designers and developers tend to relegate the LEED certification process to a point-grabbing game, rather than the way to encourage sustainable building design that its developers had intended.

Problem Statement

This analysis attempts to address the three following questions: How does a developer determine what LEED standard to achieve? Which credits are worth the capital investment? What is going too far? This analysis takes the perspective of a developer who wants to build a new LEED-rated mid-rise apartment building due to the fact that renters are typically willing to pay a higher price if they are living in a "green building." The developer faces a two-headed question: how many credits should be obtained, and which specific credits are economically, structurally, legally, and aesthetically feasible?

This analysis takes a systems approach that consists of establishing an objective function that is governed by a set of constraint equations. The objective function, below, maximizes the number of LEED credits earned for a new multi-family residence.

$$\text{Max } z = \sum_{i=1}^{\#\, of\, Credits} W_i * X_i$$

Wi is the weight of each credit. For example, a bicycle storage credit can earn the owner one point, Wi = 1, while a fuel efficient vehicles credit can earn the owner three points, Wi = 3. In this equation, Xi is the binary choice of whether the owner pursues the credit or not. If the owner selects the credit, Xi = 1, and if the owner does not select the credit, then Xi = 0.

Methods

The building model is based on a recently constructed apartment complex named Zaragon Place located on East University Avenue in Ann Arbor, Michigan. This 60,000-square foot building is comprised of 8 stories and 70 bedroom units, accommodating 196 people when fully occupied. Additionally, the building has 5,400 square feet of roof space and is oriented to the west. While this building has not actually pursued LEED certification, it is advertised as a "green" building and is therefore being used as the model for this analysis.

Cost is one of the main factors constraining the objective function. Capital costs for "going green," operation and maintenance costs (O&M), and life cycle costs per credit are presented in dollars per square foot to maintain a consistent basis.

The first constraint on the system has to do with LEED's eight prerequisites. Each LEED category has at least one prerequisite that needs to be fulfilled and is represented by the following equation:

$$X_{SS1} + X_{WR1} + X_{WR2} + X_{EA1} \dots > 8$$

Because owners have a limited sum of money to spend on a project, build cost premium must constrain the objective function. So, it is essential that the sum of the capital costs for "going green" is less than or equal to a percentage of the total build cost. Based on historical evidence, this study assumes that a 6% build cost premium serves as an adequate constraint. The build cost premium constraint can be represented by the following equation:

$$\sum \textit{Capital costs} \leq 6\%\ \textit{building cost}$$

Owners are more likely to pay for green improvements that positively influence the economic profile of the project. A rent premium is the increased rent that the owner can charge renters for living in a green building. In addition to reducing a building's burden on the environment, green residences improve physical and mental health and enhance productivity (Heerwagen 2000). According to the USGBC, rent premiums are, on average, 3% higher than market rates (USGBC 2010c). Such statistics translate monetarily to the following equation and are discounted over 20 years:

$$\sum \textit{Capital costs} \leq 3\%\ \textit{rent premium}$$

Another driver of the owner's decision-making process includes a temporal element, which is often expressed in terms of the payback period. The capital cost for "going green" has to at least break even with the savings from the O&M cost after 20 years. The constraint is illustrated below:

$$\textit{Capital cost} + \sum_{i=1}^{20} \textit{O\&M costs} \leq 0$$

Lastly, limitations exist in pursuing certain combinations of credits, which are referred to as synergies. For example, the owner can obtain a LEED point for foregoing parking (Credit SS4.3), but another credit will give the owner a point for installing charging stations for electric vehicles in the parking lot (Credit SS4.4). The owner cannot earn both credits at the same time, which can be represented by the subsequent equation:

$$SS4.3 + SS4.4 \leq 1$$

When developing these constraints and analysis, the following series of assumptions were made:

- A majority of the building's envelope and layout is fixed. This analysis therefore looks at smaller changes, such as whether the roof should be vegetated, covered by solar panels, or made of highly reflective material.

- The costs of the building have life cycle considerations. These costs include the initial capital costs for "going green" as well as O&M costs.
- Utility prices remain constant over the full life cycle. This is based on Energy Information Administration's Short-Term Energy Outlook 2010.
- A discount factor of 6% is chosen based upon a historical average of "Nominal Interest Rates on Treasury Notes and Bonds of Specified Maturities" published in the OMB Circular 94 to assess the net present value (NPV) of O&M costs over the full life cycle of the building.
- The occupancy rate for the building will remain 100% for the 20-year span. The prime campus location, in addition to the fact that green buildings typically have a 3.5% higher occupancy rate than non-green buildings, leads to the full occupancy assumption (USGBC 2010c).
- Soft costs, or those related to additional documentation, commissioning, and green design, are designated $1.50 per square foot. A report by Davis Langdon outlines that soft costs typically range from $1.00-$2.00 per square foot (Matthiessen and Morris 2004).
- No Innovation in Design credits are pursued. Such credits are difficult to quantify, too variable in nature, and subject to interpretation.

Individual credit rules and cost data were sourced from several key publications. The LEED 2009 for New Construction and Major Renovations Rating System (USGBC 2010b) served as the foundation of the authors' interpretations. The report details the rules for each LEED credit and outlines the available points for each credit. Credits that the owner would not be able to earn were identified and excluded, such as brownfield redevelopment. The cost per square foot for each remaining credit was elicited from three main reports: 1) GSA: LEED Cost Study Final Report (Steven Winter Associates, Inc. 2004), 2) LEED Cost Evaluation Study (IHS 2006), and 3) The Cost of LEED: A Report on Cost Expectations to Meet LEED 2009 for New Construction and Major Renovations (Building Green, LLC 2010)

The cost per square foot for each credit mentioned previously is the foundation of our study. Initial capital costs and O&M costs over 20 years were separately calculated from the reports or estimated when data was unavailable or conflicting. From there, a life cycle cost was obtained using the following equation.

$$\textit{Life cycle cost} = \textit{Capital cost} + \textit{O\&M cost}$$

Using Microsoft Excel Solver, a general-purpose modeling program that optimizes an objective function with given constraints, the number of credits that the developer should pursue is determined. Table 2, below, serves as a sample illustration of the variable inputs and outputs to the model. The column titled "Credit Name" represents the individual i's in the objective function. Each

Credit Name	Credit Title	Credit Amount	Yes/No	Total Earned	Capital Cost ($/SF)	O&M Renter* ($/SF)	O&M Owner** ($/SF)
SS4.2	Bicycle Storage	1	1	1	$0.01	$0.00	$0.00
SS4.3	Fuel-Efficient Vehicles	3	1	3	$0.05	$0.00	$0.46
SS4.4	Parking Capacity	2	0	0	($1.50)	$8.82	$8.82
SS5.1	Protect or Restore Habitat	1	1	1	$0.67	$0.02	$0.02
SS5.2	Maximize Open Space	1	0	0	$0.73	$0.02	$0.02

* O&M Renter- Operation and maintenance cost when renter pays utilities

** O&M Owner- Operation and maintenance cost when owner pays utilities

Table 2: Sample Optimization Model

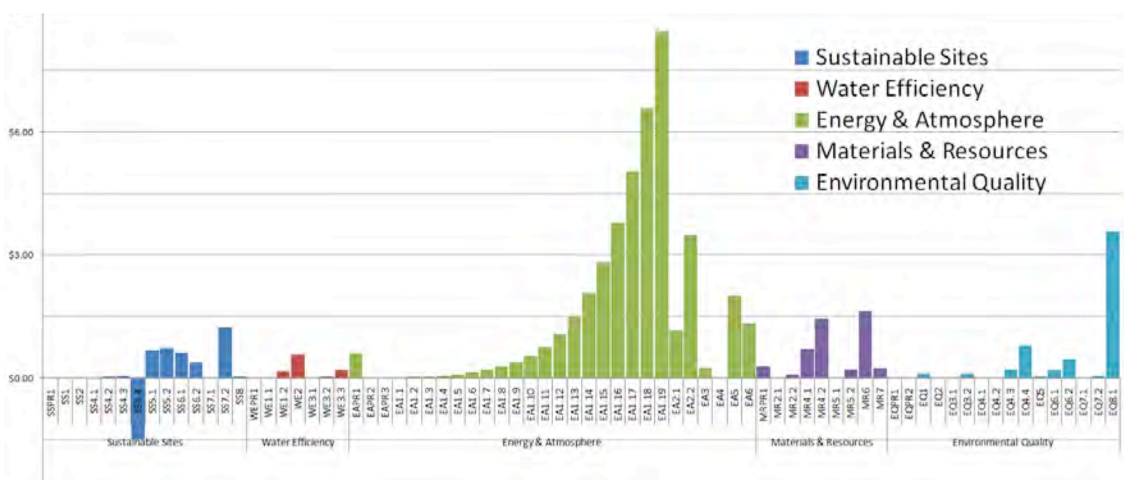

Figure 1: Capital Cost Curve

credit has an associated weight (Wi) and assigned cost data (Capital Cost and O&M Cost columns), which are inputs to the objective and constraint functions. Optimization seeks to maximize the number of total points pursued, represented in the table as the sum of the points in the "Total Earned" column.

Build cost premium, rent premium, payback period, and *synergies* constrain this maximization based upon the costs of credits chosen. Subject to these constraints, Excel Solver determines if a credit is earned, Xi. Earning an individual credit is a binary Yes/No choice, represented by a '1' for 'Yes' and a '0' for a 'No' selection. Multiplying the individual weight of the credit, Wi, by the individual binary choice, Xi, is represented by the "Total Earned" column, which is maximized by the program.

Results

Using the data collection methods mentioned above, costs for each credit were sorted by LEED category in order to develop a Capital Cost Curve (Fig. 1). In Figure 1, the most expensive credit is EQ8.1 – Daylight and Views. This is likely due to the building model's floor plan and shape; significant additions would need to be made to achieve the necessary amount of lighting. The least expensive credit is SS4.4 – Alternative Transportation/ Parking Capacity. The negative capital cost reflects the savings that the owner gains by not building a parking structure. Also of note is the exponential shape of the cost per credit for the energy reduction section (green bars). While the Energy Performance credits increase linearly from 12% to 48% in increments of 2%, it becomes more expensive to achieve an extra 2% energy reduction as the building becomes more energy efficient.

O&M costs were calculated as the NPV of each credit over a 20-year lifetime. Once again in the O&M Cost Curves, the SS4.4 – Alternative Transportation/

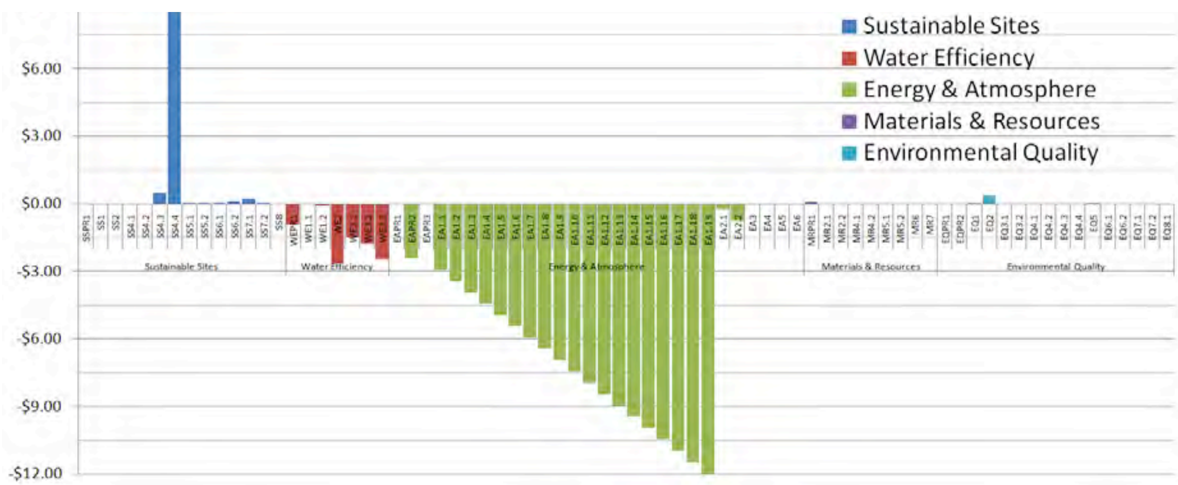

Figure 2: O&M Cost Curve – Owner Pays Utilities

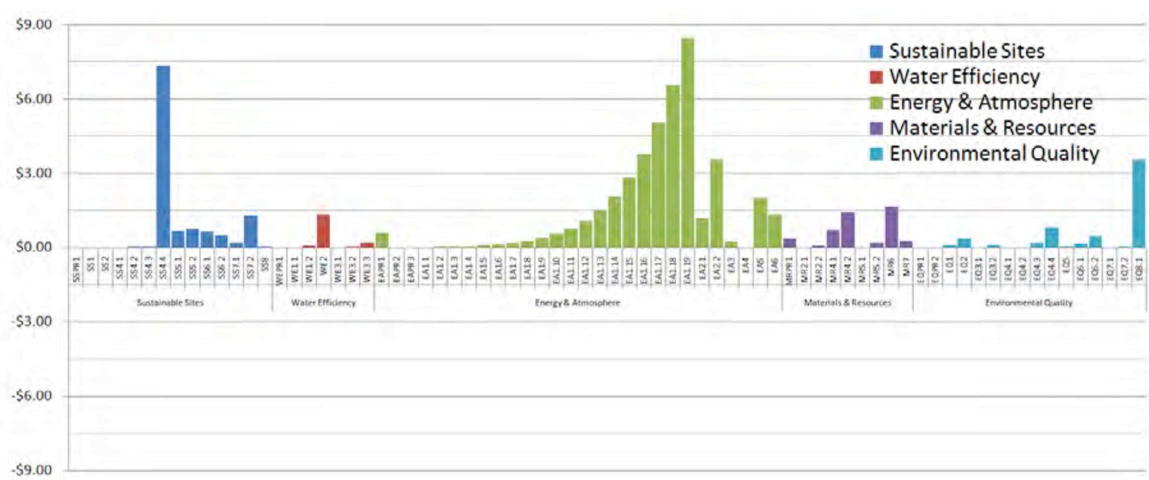

Figure 3: Life Cycle Cost Curve – Renter Pays Utilities

Parking Capacity credit stands out. This time, it is the most expensive credit due to the lost revenue that the owner incurs by not having a parking structure. In Figure 2, the owner is paying utilities and can therefore reap the benefits of increases in water and energy efficiency.

The Life Cycle Cost Curves aggregate the Capital and O&M Cost Curves to determine a value for each credit over the lifetime of the building. This was done for two different scenarios: when the owner pays utilities and when the renter pays utilities. When the renter pays utilities (Fig. 3), the Life Cycle Cost Curve will look almost the same as the Capital Cost Curve; the main difference is the now positive cost of the SS4.4 credit. However, when the owner pays utilities (Fig. 4), the water and energy efficiency credits now become savings for the owner. This encourages the owner to pursue these credits fervently to try to achieve the maximum overall savings. When the owner cannot incur savings on these water and energy credits, he/she would likely choose to maximize the amount of points per dollar spent instead.

In Figure 5, the Cost Abatement Curve is sorted from least to most expensive credit. When the owner pays utilities, his efficiency savings on certain credits may allow him to pay back premiums on other more expensive credits. However, when the renters pay utilities, the owner must make up his premiums by increasing the rent. The cost abatement curve exposes the un-optimized credits the designer would choose to pursue. Moving from left to right, the designer selects the lowest cost credits until the constraints are satisfied. However, because the credits are un-weighted, the designer is not maximizing "bang for buck". These calculations determine that the un-optimized scenario results in a LEED Silver distinction when a 3% rent premium is applied. The 59-point LEED Silver rating serves as the baseline case for the study.

Optimization reveals that strategically pursuing

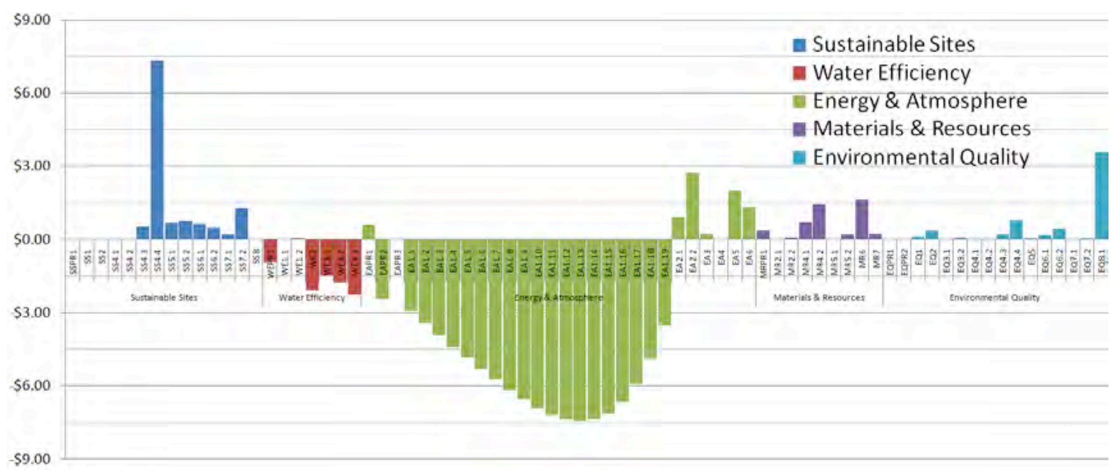

Figure 4: Life Cycle Cost Curve – Owner Pays Utilities

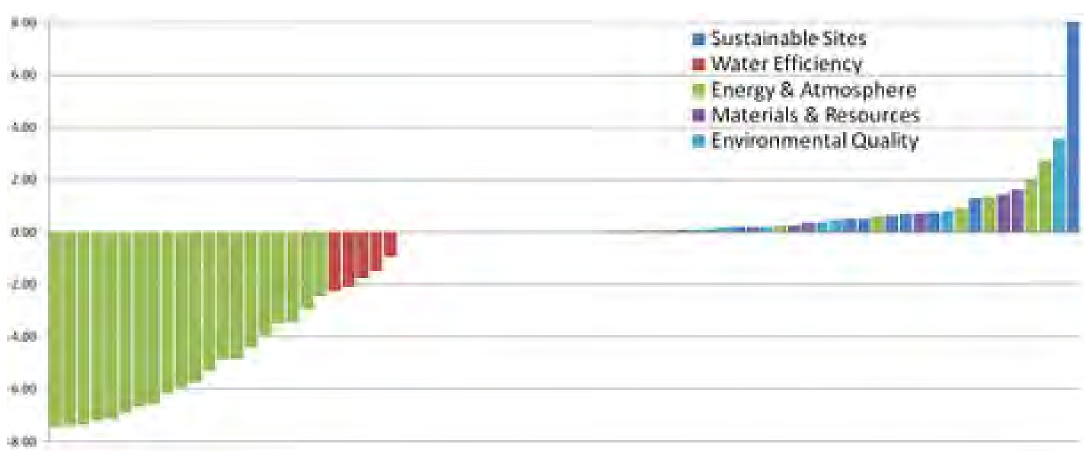

Figure 5: Cost Abatement Curve – Owner Pays Utilities

Ann Arbor – Resident Pays Utilities	1% Rent Premium	2% Rent Premium	3% Rent Premium	4% Rent Premium	5% Rent Premium
Sustainable Sites (26)	19	24	22	25	25
Water Efficiency (10)	10	10	10	10	10
Energy & Atmosphere (35)	17	14	18	20	20
Materials & Resources (14)	7	5	7	5	5
Indoor Environmental Quality (15)	11	12	12	12	12
Regional Priority (4)	4	4	4	3	3
LEED Points	68	69	73	75	75
Payback Period	19 yr	10 yr	8 yr	11 yr	7 yr
Build Cost Premium ($/SF)	$1.46	$2.91	$4.37	$5.82	$7.28

Table 3: Summary of Sensitivity Analysis

credits can result in a LEED Gold distinction under the same rent premium conditions. Out of a potential 110 available LEED points, the optimized building design earns 69 points and is eligible for a mid-range Gold distinction. A significant percentage of available credits in Sustainable Sites and Indoor Environmental Quality are obtained, as well as all credits available under Water Efficiency. Most Sustainable Sites credits are achieved as the result of a downtown site location, while Indoor Environmental Quality and Water Efficiency points are noted for low or non-existent premiums. Water Efficiency and other Energy and Atmosphere credits make even more financial sense if the owner is responsible for the utilities him/herself. The results also outline a manageable payback period of eight years, marked by an approximately $260,000 capital investment for the green features. Build cost and rent premium served as the two economic binding constraints, while payback period was a non-binding constraint.

A basic sensitivity analysis was performed on the rent premium constraint. Certainly, a sensitivity analysis could have been performed on any of the other binding constraints such as the credit cost per square foot or utility costs. Table 3, below, summarizes sensitivity results for the *rent premium* constraint.

Sensitivity analysis demonstrates the law of diminishing returns. As the table illustrates, increasingly higher rent premiums yield less and less in the way of total LEED points. As optimization approaches LEED Platinum level, high-cost credits are all that remain, which leads to an increasingly higher ceiling for each additional LEED point. Where economic changes are noticed is in the reduced payback period. The owner must determine if apartments remain affordable and desirable at these higher rent premiums, balancing issues of occupancy rate and mortgage financing.

Conclusion

Initial efforts of the study focused on identifying credit costs. The underlying reason behind the wide range of costs presented above bears some discussion. High-cost credits are typically pursued based on a number of factors related to spatial arrangement, equipment costs, labor-intensiveness, or design complexity (Matthiessen and Morris 2004). Equipment and materials such as photovoltaics and green roofs require large utilization of outdoor space. Certified wood and high-efficiency chillers are more expensive than conventional products, are difficult to acquire, and may necessitate rental of expensive construction equipment. Construction waste management and reuse plans involve additional planning. Installing ventilated flooring or daylight sensitive shades and lighting can be mechanically intricate and difficult to construct. When determining which high-cost credits to pursue, the importance of incorporating certain sustainable measures against the bottom line, such as environmental footprint, uniqueness, risk, desired image, and marketability must be considered (Cassidy 2006).

This study can assist developers by providing a framework to determine which LEED credits will add the most value to their project. It promotes the idea that developers should consider at least becoming LEED Certified for future construction projects, due to the feasibility of achieving a Silver rating. It also emphasizes that when renters pay for utilities, the developer doesn't realize the many added benefits of pursuing efficiency measures. Therefore, if a developer is serious about pursuing LEED certification, he/she should pay for utilities in order to reap the benefits of pursuing the more expensive energy and water efficiency credits.

While developers normally focus on up-front costs in their evaluation of which LEED credits to pursue, this study attempted a more thorough analysis by examining some facets that may have been overlooked. For example, the life cycle costs of each credit were considered in addition to the capital costs in order to incorporate the costs and savings that accrue over the lifetime of the building through O&M. Additionally, synergies between credits were considered because the interaction between credits can have a big impact on both the number of credits that are physically feasible and the overall efficacy of each credit in making the building more sustainable. Most importantly, for the purpose of maximizing LEED points, consideration of the weighting factor on each credit was essential in determining which credits provided the most long-term "bang for the buck." The inclusion of synergies and the weighting of the credits greatly enhance the ability to determine how to maximize the number of LEED points a building can achieve.

However, the LEED program can still be construed as a double-edged sword. On one hand, LEED draws upon the competitive nature of mankind, daring architects, engineers, and developers to innovate to the best of their abilities. A complex, multi-faceted problem is converted into a tangible game with clearly established rules and intricate strategies (Matthiessen and Morris 2004). On the other hand, sustainable design and development cannot be fully appreciated if viewed only through the lens of gamesmanship. An appreciation for synergies, the extension of system boundaries to include infrastructure planning, and an understanding of design flexibility and uncertainty are required for projects to truly be considered "sustainable." Creativity, foresight, integration, and flexibility should be increasingly valued commodities in building design.

One thing that LEED is lacking is an attention to holistic building design. A great deal of design work and flashy marketing can highlight the energy savings of many green features, yet the same savings might be accomplished by re-orienting the building from west-facing to south-facing. No points are awarded for building orientation, which showcases the limitations of the LEED program to advocate for holistic design. Optimizing LEED credits further relegates green building to a point-grabbing game.

It is understood that the presented analysis does not provide full coverage of the design-build-LEED nexus, but provides some food for thought. For example, efforts in this study did not include an analysis of local or regional incentives. Many governments provide tax incentives for LEED buildings. A city such as Portland provides significant monetary benefits to buildings that achieve Platinum status, and the city of Boston mandates that all new buildings at least achieve LEED certification. While this policy in Boston removes the potential for a market advantage, it ensures that future construction projects incorporate more sustainable practices.

Furthermore, Regional Priority Credits, new to the LEED 2009 rating system, were not considered during this evaluation. These credits are ZIP code-dependent and are earned through bonus points (maximum of four) if the developer pursues the credits that the local USGBC chapters deem as priorities for their geographic area. Regional credits allow cities to highlight specific urban needs that they believe would improve the community as a whole. For example, the six Regional Priority Credits for Ann Arbor, MI are: 1) Building Reuse, 2) Brownfield Redevelopment, 3) Access to Public Transportation, 4) Bicycle Storage & Changing Rooms, 5) Stormwater Design (Quality Control), and 6) Heat Island Effect (Roof)

While LEED needs to be adjusted to achieve more holistic building design, regional incentives and Regional Priority Credits enable cities to encourage sustainable development and emphasize the improvements they would most like to see integrated into their communities. Cities are path-dependent; future development strategies will depend on what is already present in the built environment. It is, therefore, important to include the principles of sustainable development in today's construction projects. Because LEED requires developers to address these principles as they plan their buildings, it is one tool that can help cities decrease their overall environmental footprint and encourage future sustainable urban development

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