MODELING RISK FACTORS ON EXPECTED BIDS IN CERTIFIED SUSTAINABLE CONSTRUCTION

By

JEREMY PIELA

A THESIS PRESENTED TO THE GRADUATE SCHOOL
OF THE UNIVERSITY OF FLORIDA IN PARTIAL FULFILLMENT
OF THE REQUIREMENTS FOR THE DEGREE OF
MASTER OF SCIENCE IN BUILDING CONSTRUCTION

UNIVERSITY OF FLORIDA

2010

To my Mom and my brother Jonathan

ACKNOWLEDGMENTS

I thank my parents, my brother Jonathan, and the rest of my family for their continuing support of my academic ventures. Leaving a career in Connecticut and returning to school was a very difficult decision for me, and would have been impossible without their support. I also thank the wonderful friends that I have made at the University of Florida who were extremely important in the success that I enjoyed in my pursuit of the advanced degree associated with this project. I not only made lifelong friends, but learned lessons from those friendships that are beyond value and will surely be the key to my success in the future. I finally thank the faculty and staff of the Rinker School of Building Construction at the University of Florida for their efforts that have made my experience there so enjoyable.

TABLE OF CONTENTS

page

ACKNOWLEDGMENTS 4

LIST OF TABLES 8

LIST OF FIGURES 10

LIST OF ABBREVIATIONS 11

ABSTRACT 12

CHAPTER

1 INTRODUCTION 13

Background 13
Problem Statement 14
Risk Study 14

2 LITERATURE REVIEW 17

Green Building 17
LEED 17
Davis Langdon 2004 19
Increased Risk 21
Cost of LEED 21
Proximity to Services 22
Bidding Climate and Culture 23
Number of Bidders 24
Other potential projects 24
Experience of bidders 25
Intent and Values of the Project 25
Climate 26
Timing of Implementation 27
Size of Building 27
Point Synergies 28
LEED Associated Risk 28
Sustainable Sites 28
Water Efficiency 29
Energy and Atmosphere 30
Materials and Resources 31
Indoor Environmental Quality 32
Innovation in Design 33
LEED Credits Affected 33
Risk to the Contractor 34

Contracts 38
Risk Analysis 38
External Risk 39
Internal Risk 40
Risk Balance 40
Levels of Risk 41
Zero Risk 41
Approval-Compensation 41
Utility Based Criteria 42
Risk Criterion 42
Risk Factors 44
Risk in Bidding 46
Risk Compensation 47
Winners Curse 48
Risks Associated with the Winner's Curse 50
Identifying the Winner's Curse 51
Experienced Bidders 52
Risk and HPB 53
Bidding Model (Tang et al. 2006) 53
Model Factors 54

3 METHODOLOGY 57

Standard Building Characteristics 57
Level of Certification 60
Soft Costs 61
Risk Aversion 61
Perceived Value; c_i 62
High Bid; c_h 63
Number of Bidders; n 63
Risk Behavior; δ 64
Experience 65
Location 66
Assumptions 68
Calculations 69
Calculation Table 69

4 ANALYSIS 73

Example Project 73
Project 73
Bidder 73
Analysis 73
Base Price 73
Level of Certification 73
Baseline Case 74
Bid Climate 76

Risk Aversion 77
Location 78
Soft Costs 79
Expected Costs 80
Results 80
Sensitivity Analysis 82
Certified Level Building 82
Silver Level Building 82
Gold Level Building 83
Platinum Level Building 83
Risk Aversion 84
Number of Bidders 84
Experience 85

5 SUMMARY AND CONCLUSIONS 89

Summary 89
Conclusions 89

6 RECOMMENDATIONS FOR FURTHER STUDY 92

APPENDIX: SUPPORTING DATA 94

LIST OF REFERENCES 97

BIOGRAPHICAL SKETCH 99

LIST OF TABLES

Table page

2-1 Rating categories and points available under LEED-NC v2.2. 19

2-2 Rating levels and associated point totals under LEED-NC v2.2. 19

2-3 Effects of demographic density on feasibility of LEED-NC v2.2 credits 23

2-4 Costs associated with bidding climate. 24

2-5 Effects of climate on cost of LEED construction 26

2-6 Contractor's risk responsibilities related to Sustainable Sites, LEED-NC v2.2 ... 29

2-7 Contractor's risk responsibilities related to Water Efficiency, LEED-NC v2.2 30

2-8 Contractor's risk responsibilities related to Energy and Atmosphere.................. 30

2-9 Contractor's risk responsibilities related to Materials and Resources................. 31

2-10 Contractor's risk responsibilities related to Indoor Environmental Quality. 32

2-11 Contractor's risk responsibilities related to Innovation in Design. 33

2-12 Total number of LEED-NC v2.2 credits that affect risk to the contractor 34

2-13 Methods of dealing with risk and risk acceptance compensation policies. 43

2-14 Additional costs based on experience. 44

2-15 Percentages of bid based on the difference range of bids tendered.................. 51

3-1 Percentage increases in cost of LEED certification from GSA 2004 study. 60

3-2 Estimates of LEED related soft costs 61

3-3 Economic factor multipliers for the base case of the risk model. 64

3-4 Table for determination of the risk factor for a particular contractor.................... 64

3-5 Determination of experience factor for a specific bidder.................................... 65

3-6 Factors for determining costs related to the proximity to urban centers 66

3-7 Percentage increase in LEED costs as related to climate 67

3-8 Calculations for Location Factor. 67

3-9 LEED Premium and Bid Amount calculation table. 72
4-1 Expected LEED costs for example 55,000 square foot classroom 74
4-2 Calculation of costs in the baseline scenario. 75
4-3 Determination of baseline analysis. 76
4.4 Determination of baseline analysis. 76
4-5 Economic factor determination 77
4-6 The determination of the Experience Factor 77
4-7 Determination of the number of bidders. 77
4-8 Determination of bidder's Risk Aversion Factor 78
4-9 Risk Aversion calculation 78
4-10 Adjustment factors for location of the example project. 79
4-11 Estimated Soft Costs 80
4-12 Comparison of baseline case to example scenario. 80
4-13 Results of model calculations 81
A-1 Supporting data for sensitivity analysis. 94

LIST OF FIGURES

Figure page

2-1 Effects of risk on the cost of a LEED certified building. 22

2-2 Display of the flow of risk associated with a LEED certified project. 35

2-3 LEED related risks to contractors. 37

2-4 Elements of project related risk from Alquien 1999. 40

3-1 Cost per square foot of college classroom facilities 58

3-2 Cost per square foot of college dormitory facilities 58

3-3 Cost per square foot of college student union facilities..................................... 59

3-4 Cost per square foot of college student union facilities..................................... 59

3-5 Interactions of the factors and costs associated with the LEED premium. 69

4-1 Graphical representation of the effects on a Certified level building. 85

4-2 Graphical representation of the effects on a Silver level building. 86

4-3 Graphical representation of the effects on a Gold level building. 86

4-4 Graphical representation of the effects on c a Platinum level building 87

4-5 The effects of various risk aversion behaviors 87

4-6 The effect of the number of bidders 88

4-7 The effects of the level of experience 88

5-1 Effects of the number of bidders on a LEED Gold project. 90

LIST OF ABBREVIATIONS

HPB	High-Performance Building
LEED	Leadership in Energy and Environmental Design
LEED-NC v2.2	Leadership in Energy and Environmental Design rating system for New Construction and Major Renovation, version 2.2
USGBC	United States Green Building Council

Abstract of Thesis Presented to the Graduate School
of the University of Florida in Partial Fulfillment of the
Requirements for the Degree of Master of Science in Building Construction

MODELING RISK FACTORS ON EXPECTED BIDS IN CERTIFIED SUSTAINABLE CONSTRUCTION
By

Jeremy Piela

August 2010

Chair: James G. Sullivan
Cochair: R. Raymond Issa
Major: Building Construction

Current research shows that a high-performance building (HPB) that is certified as such under a rating system such as the Leadership in Energy and Environmental Design (LEED®) building rating system developed by the United States Green Building Council (USGBC) demonstrate an increase in construction costs over the cost of traditional projects that do not pursue LEED certification (Steven Winter Associates 2004). This increase is often evident in projects that are produced by designers, builders and other involved parties that have extensive experience and education in the construction of buildings that incorporate many of the design features and construction techniques that are included in HPBs. The purpose of this study is to propose a model that examines potential cost increases over traditional buildings of similar construction.

This study reviews bid strategy and risk aversion models to explain the impacts of certification level, experience, location, perceived risk, and the risk behaviors of bidding contractors on the pricing of high-performance buildings. This study proposes that this increase in costs is related to the perceived risk involved in the construction of a project that pursues green certification, the level of certification pursued, and the individual risk behaviors of the contractors that are operating in a particular bidding climate.

CHAPTER 1
INTRODUCTION

Background

Sustainable construction is becoming a more popular form of construction in the industry today. As society becomes more aware of the problems that have been created by the practices that have been utilized in the past, the construction industry is becoming more aware of the repercussions of the materials and techniques that are used to develop modern buildings. The built environment consumes an enormous amount of the resources that are used today, as well as producing a large amount of waste. Recently, there has been a shift in thinking towards being more responsible with the resources that are consumed and the wastes that are generated. In the construction industry, this has resulted in the construction of buildings that are more responsible in terms of material use, energy use, and the health of the building occupants.

In response to these concerns, there has been the development of building rating systems that help to gauge the level of sustainability that is built into a structure. Today, there are many different systems throughout the world, each with varying popularity. One of the most popular in the United States is the Leadership in Energy and Environmental Design (LEED) building rating system. This system has been proven to reduce the amount of energy that is consumed in buildings, and is also concerned with the reduction in waste materials, the responsible use of materials, and the health of building occupants.

While there is some debate over the effectiveness of the rating system, there is generally agreement that these types of systems are helping the construction industry to produce buildings that are more environmentally responsible. As these systems gain popularity, this type of construction is becoming more of the norm in the built environment.

Problem Statement

Sustainable construction is generally accepted to be more expensive than standard construction projects. This increase in costs pervades even in the presence of contractors that are experienced in this type of construction. As this type of construction becomes the norm, this increase of costs should begin to disappear, as there is no substantial difference between the rated structures and ones that are not certified. Certified buildings cost more than similar, non-certified buildings and this study will propose a framework to account for those costs.

Risk Study

This study will aim to define and rationalize the reasons for the increases that are evident in the construction of certified buildings. The LEED building rating system will be studied, as there exists a large amount of data that is accessible due to the popularity of the system. This study will equate the additional costs to additional risk that is assumed by the contractor. These risks will be shown to arise from the perception that these projects are innovative and unique, and therefore pose a latent risk of loss to the contractor that is in excess of the risk that is assumed in a standard construction project.

Chapter 2 is a review of the literature that exists in this area of study. The history of the LEED system will be addressed, and the rating system will be further examined to help identify possible explanations for this cost increase. The origins of this cost and the underlying risk will be examined. This will include an analysis of the contract language that can affect the amount of risk that is assumed by a contractor. A thorough analysis of the points that are available under the LEED rating system and the risks associated with pursuing these points will be included.

Included in the Chapter 2 literature review will be an analysis of the types of risk that a contractor must deal with, and the techniques that are used to deal with risk. These risk analyses will be carried into a discussion of the effects of risk in the environment of an auction where contractors submit bids for the construction of a project. Methods and models that help to determine expected bids will be examined.

Chapter 3 will introduce the model that was developed as part of this study that will be used to evaluate and predict the bids that are submitted by a particular contractor for a specific project, using the factors that are laid out in various cost studies that relate to certified sustainable construction. The model consists of several factors, all of which are laid out in detail in this chapter. This model is developed using a computerized spreadsheet and the set up of the model is explained in detail. The methodology of the model will be laid out in this section, including the relationships of the variables that are proposed.

Chapter 4 will propose a sample scenario that will be used to show the relationships that exist in the model. This example will consist of the construction of a fictional structure on a college campus in the southeast United States that is seeking certification under the LEED rating system. The associated costs with different levels of certification will be examined for this particular scenario. The proposed model will be used to examine this sample scenario, and a thorough analysis of the results will be included. This sample scenario is produced using a fictional company and project, and some of the variables will be assumed. This model is meant to produce real world results, but in this study will only be used to examine and evaluate the relationships between the risk variables that are involved.

Chapter 5 will include a summary of the study, as well as conclusions that the author has reached. Chapter 6 will consist of a discussion of the limitations of this study and recommendations for further research.

CHAPTER 2
LITERATURE REVIEW

Green Building

High-performance buildings (HPB) are buildings that fulfill needs in the built environment utilizing many of the best methods of conventional construction coupled with the latest high-performance approaches to construction in areas such as energy reduction, water reduction, indoor environmental quality, and occupant health. HPBs are becoming increasingly prevalent in the United States due to several primary reasons including (Kibert 2008):

- HPB construction provides an ethical and practical response to issues of environmental impact and resource consumption. This includes a greater reliance on renewable resources for energy, recycling and reuse of water and other materials, native landscaping, passive design considerations and other accepted practices that reduce environmental impacts and resource consumption of the built environment.
- From a life-cycle cost (LCC) perspective, which examines first costs, performance, and maintenance, HPBs are almost always a more attractive investment. While many of the strategies employed are more expensive on a first-cost basis, this initial cost is usually recouped quickly. This effect is exacerbated by increases in energy and other resource costs due to increasing demand and diminishing supply.
- Design and construction of HPBs take into account the effect of the building and its operation on the health and well-being of the building's future occupants. Building related illness is a relevant concern, as lost productivity has been estimated to exceed $150 billion per year (Kibert 2008). Strategies include protection of ductwork during construction to prevent contamination; specifying finishes with little or no volatile organic compounds (VOCs) to prevent potential off-gassing; and utilizing techniques to limit mold and bacteria growth inside of the structure.

LEED

Modern buildings that seek to be considered as high-performance have several different building rating systems that may be utilized to certify that a building attains a certain level of performance. One rating system in the United States is the Leadership in Energy and Environmental Design (LEED) building assessment tool produced by the United States Green Building Council (USGBC). This system is useful for gauging the level of sustainability, or greenness in a building (Mathiessen and Morris 2004). The LEED system "provides third party verification that a building or community was designed and built using strategies aimed at improving performance across all the metrics that matter most: energy savings, water efficiency, CO2 emissions reduction, improved indoor environmental quality, and stewardship of resources and sensitivity to their impacts (USGBC 2010)."

LEED is a standard that is used to measure the level of sustainable measures that are incorporated into the design and construction of a building. For the purposes of this study, the LEED-NC rating system will be used. LEED-NC is for new construction and major renovation (greater than 50% of the occupied space is affected). The system provides a framework that awards points under several categories that results in a total score for the building, and a corresponding rating level of Certified, Silver, Gold, and Platinum. The LEED rating system has gone through many changes since its inception in 1998 as a pilot program. More recent versions according to the USGBC (2010) website have been LEED-NC v1.0 (1999), LEED-NC v2.0 (March 2000), LEED-NC v2.1 (November 2002), LEED-NC v2.2 (October 2005), and LEED-NC v3 (April 2009).

The LEED version that this study addresses is the LEED-NC 2.2 rating system. While this study was performed during the tenure of the LEED-NC v3 system, there was very little information published about projects under this format. As projects are registered with the USGBC, they are registered under a rating system and follow that system through completion. Due to this, there is a useful amount of information that was available at the time of this study related to the LEED-NC v2.2 rating system, and projects using this system were examined. While much of the information introduced in this study can be used under different systems, it should be noted that the information used and studies cited in this study related to the LEED-NC v2.2 rating system.

Table 2-1 displays the points available in each category and Table 1-2 shows the points related to each level of certification under the LEED-NC v2.2 rating system.

Table 2-1. Rating categories and points available under LEED-NC v2.2.

Point Category	Available Points
Sustainable Sites	14
Water Efficiency	5
Energy and Atmosphere	17
Materials and Resources	13
Indoor Environmental Quality	15
Innovation and Design	5
Total Points Available:	69

Table 2-2. Rating levels and associated point totals under LEED-NC v2.2.

Rating Level	Project Point Total
Certified	26 - 32
Silver	33 - 38
Gold	39 - 51
Platinum	52 - 69

The higher the levels of certification require a significant concerted effort from the owner, designer, contractor and the rest of the project team to achieve. This can often be at a high additional cost.

Davis Langdon 2004

The Davis Langdon study of 2004 compared a database of completed buildings in order to compare the construction HPBs where LEED certification was a primary goal to similar buildings where LEED certification was not considered. The 2004 study reviewed 138 buildings; 93 that were non-LEED and 45 that were LEED-seeking projects. The prices were normalized for location and time to ensure consistency of the measurements. It should be noted that many of these projects that were not designed with the LEED rating in mind would have achieved several LEED credits, though this was not the intention of the project from the design stage. This study covered several types of buildings including academic buildings, laboratory buildings, and library buildings. The Davis Langdon study drew four key conclusions from the analysis regarding the construction costs of LEED versus non-LEED seeking projects:

- There is a very large variation in costs of buildings, even within the same building program category
- Cost differences between buildings are due primarily to program type
- There are low cost and high cost green buildings
- There are low cost and high cost non-green buildings

The Davis Langdon study in fact found that there are no statistically significant differences between the cost per square foot between LEED seeking and non-LEED seeking buildings. The 2004 study concludes that the variation in the cost of all buildings makes the price difference in LEED construction not discernable from the normal variation. The 2007 follow-up to this study again confirmed these conclusions, using the latest data available at the time of the study.

While the Davis Langdon study shows evidence that there is no significant difference in the cost of LEED certified buildings and buildings that do not pursue certification, other studies have shown that there is a difference in the costs of green buildings that are submitted for bid, such as the GSA study of 2004 (Steven Winter Associates 2004).

Increased Risk

The difference in price that exists in the construction bidding environment stems from the risk that is associated with construction with the goal of certification under a system such as LEED. This risk arises from the additional burden placed on the contractor to deliver a building that meets a certain criteria. With the added innovation and planning comes risk, and risk management is the main consideration when managing creative projects (Alquier 1999). There is often included in the contract language a requirement for the contractor to ensure that the building performs up to a certain level of sustainable certification, and failure to achieve this goal and the associated economic costs are certainly a risk. Many of these buildings, particularly at higher levels of certification, can be quite innovative and unique, which can present substantial additional risk. "Green building embodies a greater latent potential for unrealized expectations, misunderstandings, physical or economic failure, and litigation (Anderson 2010)."

Cost of LEED

This study proposes that this increase in costs is related to the perceived risk involved in the construction of a project that pursues green certification, the level of certification pursued, and the individual risk behaviors of the contractors that are operating in a particular bidding climate. Since these additional risks pose a latent potential cost to the contractor, there is a cost increase that is associated with the additional risk that is passed on to the building owner. These costs are mapped out in Figure 2-1. The Davis Langdon study of 2004 identified seven particular factors that affect the cost and feasibility of a LEED certified project. The factors and the effects that they have on the cost of LEED construction are laid out in seven sections.

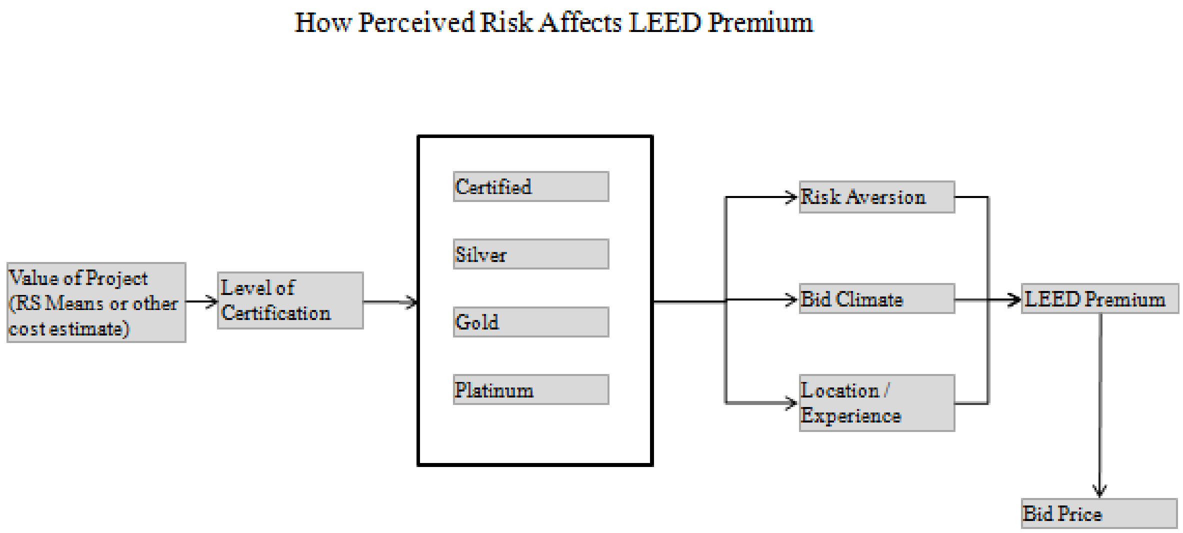

Figure 2-1. Effects of risk on the cost of a LEED certified building.

Proximity to Services

Location can have a considerable impact on the cost and feasibility of certain LEED points. Of the points that are affected by location, five are generally available in a rural location, while six to eight are available in an urban location, though two of these points may come at an increased cost over the cost associated with rural construction. The LEED system is weighted toward the development of urban environments. The community connectivity and development density requirements, as well as the public transportation access credit are direct results of this. The credits that are affected by the demographic location are listed in Table 2-3. As well as an increase in available credits, urban environments are more likely to have a well established construction waste recycling or reclamation program. In addition to the availability of services, contractors are also more likely to be familiar with these practices in an urban setting, presenting a more sophisticated pool of potential bidders. Infrastructure that is conducive to the construction of a LEED structure may also exist to a greater extent in an urban environment.

Table 2-3. Effects of demographic density on feasibility of LEED-NC v2.2 credits. $$$ indicates that the credit may be available, though at an increased cost. Figure generated from data found in Steven Winter Associates 2004.

	Location	
Point Category	Rural	Urban
Site Selection		X
Urban Redevelopment		X
Alternative Transportation, Public Transportation Access		X
Reduced Site Disturbance, Public Transportation Access	X	
Reduced Site Disturbance, Development Footprint	X	
Stormwater Management, Rate and Quantity	X	$$$
Stormwater Management, Treatment	X	$$$
Water Efficient Landscaping, Reduce by 50%	X	
Water Efficient Landscaping, No Potable Use or No Irrigation		X
Construction Waste Management, Divert 50%		X
Construction Waste Management, Divert 75%		X
Total Points Available	5	6 to 8

Bidding Climate and Culture

The bidding climate is potentially the most significant factor in the cost of a high performance building. The bidding climate is the response of the contractors to the specific requirements of building performance laid out in the contract. The culture of the entities and relationships between them will also have an effect on the resulting behavior of the participating contractors. These costs consist of two components; actual costs borne by the contractor, and the perceived risk associated with the building performance requirements. Some of these costs are further defined in Table 2-4. The actual (physical) costs are relatively small, while the cost associated with risk can be much larger. This will be examined more thoroughly in this study, since this factor is the one that most extensively drives the cost of LEED construction.

Table 2-4. Costs associated with bidding climate.

Direct Costs	Risk Associated
Documentation Costs	Liability
IAQ Costs	Smaller Bidder Pool
Schedule Impacts	Local Familiarity with Sustainable Building

There are many factors related to the amount of the cost of risk, but there are two major reasons for the increase of cost for wary bidders:

- Bidders are inclined to add contingencies or risk premiums to cover the perceived risk
- As bid pool diminishes, competition lessens and bid prices increase

As the number of bidders increases, a bidder realizes that to win the auction, they must bid more aggressively, but the presence of more bidders also increases the chance that if the contract is won, the winner will suffer a loss (Thaler 1988). This phenomenon is called the "winner's curse" and is described in detail in this report in the section titled "Winner's Curse."

Number of Bidders

The number of bidders is also affected by other factors. The strength of the economy plays a part in the determination of the number of bidders. During a period of strong economic growth, there are more projects on the market that the contractor could potentially bid on. Bidders are more likely to bid on projects that are perceived as less risky if the jobs are available.

Other potential projects

Contractors will be less likely to bid on a project perceived as risky if there is a large amount of other work available. A contractor, as any other entity, is generally considered to be risk averse and therefore does not pursue unnecessary risks. If there is a large amount of work that is available to the contractor that is perceived as less risky, there are likely to be a smaller number of bidders that are willing to offer a bid on a project that contains any added risk. The opposite is also true. In a period when the economy is struggling, there is likely to be a larger pool of contractors that are willing to take on a larger amount of risk than at other times simply because there is less work available. An increase in the number of bidders has the general result of reducing the bid price offered, though this is a general rule and can be affected by other factors.

Experience of bidders

The second is the experience of the bidders that are participating in the auction. More experience with LEED associated projects will cause the perceived risk to the experienced contractor to be less than that of the inexperienced contractor. This has the effect of lowering the amount of the bid. This phenomenon is more completely discussed in the “Experienced Bidders” section of this report.

The two factors that have the greatest effect are the familiarity of the bidding community with green building, and the availability of alternative work in the construction market in the local area of the project. Attempting a project where high performance building is an unfamiliar concept and/or where contractors are unwilling to offer bids can significantly affect the cost of the project. Local and regional design standards, as well as building codes and initiatives will have an effect.

Intent and Values of the Project

This category describes the effect of the intents and values of the owner and project team as related to the project. The best and most economical sustainable designs are ones in which the features are incorporated at an early stage into the project, and where the features are integrated, effectively supporting each other (Mathiessen and Morris 2004). If members of the project team, particularly the owner, are not fully invested in incorporating high performance aspects into the project, it will be more difficult to include these changes into the project. This largely hinges on fully understanding the intents and desires of the owner and design team. These are difficulties that the contractor has little or no control over and therefore represents a risk to the contractor.

Climate

The climate that a building is constructed in has an effect on the feasibility of certain LEED points, and the cost associated with certain levels of LEED certification. This factor refers to the natural environmental climate of the location of the project. Mathiessen and Morris described values associated with location in the Davis Langdon study of 2004. This is shown in Table 2-5.

Table 2-5. Effects of climate on cost of LEED construction (Mathiessen and Morris 2004).

	% Increase Based on Certification Level			
Location	Certified	Silver	Gold	Platinum
Mild Coastal	-	1.00%	2.70%	7.80%
California Central Valley	-	3.70%	5.30%	10.30%
Gulf Coast	-	1.70%	6.30%	9.10%
Northeast Coast	-	2.60%	4.20%	8.80%
Rocky Mountain	-	1.20%	2.80%	7.60%
Average Increase:		2.04%	4.26%	8.72%

The Davis Langdon study took into effect the cost of energy and the amount of energy consumed, altering the effectiveness of the energy efficiency measures. This difference in calculation is included in the associated costs. These increases were derived from a study that took an actually constructed building in Santa Barbara, California and placed it in five hypothetical environmental locations. These locations were defined as:

- Mild Coastal – Santa Barbara and San Francisco
- California Central Valley – Merced
- Gulf Coast – Houston
- Northeast Coast – Boston
- Rocky Mountains – Denver

Yearly temperature fluctuations and humidity levels can play a significant role in determining cost for mechanical systems, and the feasibility of passive heating and cooling.

Timing of Implementation

The timing of implementation of a building rating system can also have an effect on the cost and feasibility of achieving a level of building certification. This factor was not covered in the Mathiessen and Morris (2004) study since this is extremely difficult to quantify and measure. This would be a situation specific factor that would have to be closely analyzed before a project was undertaken.

Size of Building

The size of the building also has an effect on the cost of LEED certification. This is most notable in the direct cost of the building, but the cost of perceived risk also increases as a factor of this cost. As the value of the project increases, the costs associated with risk also increase. Many of these risks are proportional to the total cost of the project, and will rise as the overall cost of the project increases. If a contractor were to run late on a project, the damages that the contractor could be held responsible for could be increased for a larger project. Litigation costs will generally also be tied to the overall value of the project that is in question, and penalties associated may be tied to the overall project value, or the potential value to the owner or other financially interested party.

Point Synergies

The points under the LEED system that are pursued also have an effect on the cost of certification. Some points are synergistic and can assist in obtaining other points, lowering the overall cost of a certain level of certification.

LEED Associated Risk

The 2006 Davis Langdon study addressed each category and related costs to each of the LEED credits. Some credits had little or no associated costs, while others were very expensive. As with costs, there are risks that fall squarely into the field of work for certain project members. There are relatively few credits that are the direct responsibility of the contractor, as the LEED system is weighted heavily towards the design of the project. Table 2-6, Table 2-7, Table 2-8, Table 2-9, Table 2-10, and Table 2-11 outline the specific credits that fall to some extent under the responsibility of the contractor, and therefore represent risk to the contractor.

Sustainable Sites

The Sustainable Sites category of the LEED-NC v2.2 rating system is in place to help reduce the impact of the built environment on the natural environment. The credits include stormwater and pollution prevention, site selection that encourages use of previously developed land, and increased use of alternative transportation.

The contractor has little responsibility for most of the Sustainable Sites credits. Note that there is a perceived risk for Prerequisite 1. This credit usually does not require any additional activities above and beyond a standard construction project, but under the LEED rating system this takes on a greater significance. If the contractor fails to follow local pollution prevention plans, or fails to document compliance, the LEED certification could be forfeit since this is a prerequisite. This represents a significant additional risk to the contractor. The risks are outlined in Table 2-6.

Table 2-6. Contractor's risk responsibilities related to Sustainable Sites, LEED-NC v2.2.

(LEED 2.2 Rating System) Sustainable Sites	Risk to Contractor? Yes	No
SS Prerequisite 1: Construction Activity Pollution Prevention	X	
SS 1: Site Selection		X
SS 2: Development Density and Community Connectivity		X
SS 3: Brownfield Redevelopment		X
SS 4.1: Alternative Transportation - Public Transportation Access		X
SS 4.2: Alternative Transportation - Bicycle Storage and Changing Rooms		X
SS 4.3: Alternative Transportation - Low-Emitting and Fuel-Efficient Vehicles		X
SS 4.4: Alternative Transportation - Parking Capacity		X
SS 5.1: Reduced Site Disturbance - Protect or Restore Habitat	X	
SS 5.2: Reduced Site Disturbance - Maximize Open Space		X
SS 6.1: Stormwater Management - Quantity Control	X	
SS 6.2: Stormwater Management - Quality Control	X	
SS 7.1: Heat Island Effect - Non-Roof		X
SS 7.2: Heat Island Effect - Roof		X
SS 8: Light Pollution Reduction		X

Water Efficiency

The Water Efficiency category of the LEED-NC v2.2 rating system is in place to encourage more efficient use of water resources. This includes reduction of water use, reduction or elimination of potable water use for landscaping, and innovations in the treatment of wastewater. The Water Efficiency credits are all related to the design of the project and pose little if any direct risk to the contractor. The risk responsibilities concerning the contractor are outlined in Table 2-7. The contractor should be aware of these credits so that any additional planning that may be required is incorporated into the schedule.

Table 2-7. Contractor's risk responsibilities related to Water Efficiency, LEED-NC v2.2.

(LEED 2.2 Rating System) Water Efficiency	Risk to Contractor? Yes	No
WE 1.1 and 1.2: Water Efficient Landscaping - Reduce by 50% and No Potable Use or No Irrigation		X
WE 2: Innovative Wastewater Technologies		X
WE 3.1 and 3.2: Water Use Reduction - 20% and 30% Reduction		X

Energy and Atmosphere

The Energy and Atmosphere category of the LEED-NC v2.2 rating system is in place to encourage the reduction in the use of energy and the reduction of the use of harmful refrigerants in building systems. This includes the reduction of overall building energy use, commissioning of building systems, and the production or purchase of renewable energy. The analysis of these risks are outlined in Table 2-8.

Table 2-8. Contractor's risk responsibilities related to Energy and Atmosphere, LEED-NC v2.2.

(LEED 2.2 Rating System) Energy and Atmosphere	Risk to Contractor? Yes	No
EA Prereq. 1: Fundamental Commissioning of Building Systems		X
EA Prereq. 2: Minimum Energy Performance		X
EA Prereq. 3: Fundamental Refrigerant Management		X
EA 1: Optimize Energy Performance (1-10 points)		X
EA 2: On-Site Renewable Energy (1-3 points)		X
EA 3: Enhanced Commissioning		X
EA 4: Enhanced Refrigerant Management		X
EA 5: Measurement and Verification		X
EA 6: Green Power		X

The Energy and Atmosphere category has little effect on the performance of the contractor. This is generally a design category and is a cooperative effort between the designers and installers of the building systems. Again the contractor should be aware of these credits so that the schedule may be adjusted accordingly.

Materials and Resources

The risks that are presented to the contractor are outlined in Table 2-9. The Materials and Resources category of the LEED 2.2 rating system is in place to promote the reuse and recycling of building materials, as well as materials that are considered sustainably harvested or produced locally.

Table 2-9. Contractor's risk responsibilities related to Materials and Resources, LEED-NC v2.2.

	Risk to Contractor?	
(LEED 2.2 Rating System) Materials and Resources	Yes	No
MR Prerequisite 1: Storage and Collection of Recyclables		X
MR 1.1 to 1.3: Building Reuse	X	
MR 2.1 and 2.2: Construction Waste Management - Divert From Landfill	X	
MR 3.1 and 3.2: Materials Reuse	X	
MR 4.1 and 4.2: Recycled Content	X	
MR 5.1 and 5.2: Local/Regional Materials	X	
MR 6: Rapidly Renewable Materials	X	
MR 7: Certified Wood	X	

The risk associated with the Materials and Resources category falls squarely in the realm of the project responsibilities of the contractor. The Building Reuse credit requires the contractor to develop a construction plan that must be followed through to preserve the required proportion of the building. The Construction Waste Management credit is perhaps the only credit that is the direct responsibility of the contractor. An experienced contractor should be familiar with this type of requirement, but the related risk is the direct responsibility of the contractor. The risk for credits MR 3 – MR 7 stems mainly from the procurement of the proper materials and the maintenance of the documentation that is necessary to show compliance with the credit requirements.

Indoor Environmental Quality

The Indoor Environmental Quality portion of the LEED 2.2 rating system is in place to help protect the health and well-being of the inhabitants of the building. The risk to the contractor is outlined in Table 2-10. While much of this category is the responsibility of the design team, the contractor holds some responsibility for following through with the designed plans.

Table 2-10. Contractor's risk responsibilities related to Indoor Environmental Quality.

	Risk to Contractor?	
(LEED 2.2 Rating System) Indoor Environmental Quality	Yes	No
EQ Prerequisite 1: Minimum IAQ Performance		X
EQ Prerequisite 2: Environmental Tobacco Smoke (ETS) Control		X
EQ 1: Outdoor Air Delivery Monitoring		X
EQ 2: Increase Ventilation		X
EQ 3.1: Construction IAQ Management Plan - During Construction	X	
EQ 3.2: Construction IAQ Management Plan - Before Occupancy	X	
EQ 4.1 to 4.4: Low Emitting Materials	X	
EQ 5: Indoor Chemical and Pollutant Source Control		X
EQ 6.1: Controllability of Systems - Lighting		X
EQ 6.2: Controllability of Systems - Thermal Comfort		X
EQ 7.1: Thermal Comfort - Design		X
EQ 7.2: Thermal Comfort - Verification		X
EQ 8.1: Daylight and Views - 75% of Spaces		X
EQ 8.2: Daylight and Views - 90% of Spaces		X

There are a few credits in the Indoor Environmental Quality category that pose potential risk to the contractor. EQ 3.1 relates to the protection of materials and the HVAC system during the construction process. EQ 3.2 does not directly involve the contractor, but must be incorporated into the contractor’s construction schedule. If the contractor failed to plan for an appropriate amount of time for these activities, the schedule may be extended beyond the required date of substantial completion. The risk is that the contractor may be responsible for not delivering the project on time if this credit is not appropriately planned for. EQ 4.1 to 4.4 would likely fall into the contractor's risk area, unless the materials to be used were expressly specified in the contract documents.

Innovation in Design

The Innovation in Design category of the LEED-NC v2.2 rating system is used to award exemplary performance in one of the listed categories or the utilization of innovative technologies or other methods that improve building performance. Risks to the contractor are outlined in Table 2-11.

Table 2-11. Contractor's risk responsibilities related to Innovation in Design.

(LEED 2.2 Rating System)	Risk to Contractor?	
Innovation in Design	Yes	No
ID 1-4: Innovative Design (projects average two of these credits)	X	
ID 5: LEED Accredited Professional		X

Most of the projects in the Davis Langdon study received two points in the Innovation in Design category for credits other than the LEED Accredited Professional credit. These credits were almost always for exemplary performance in the categories where this is an option. It is assumed that the contractor could have some risk responsibility in these credits as the study did not address which credits were involved.

LEED Credits Affected

The total number of points may vary depending on the contract language, the type of project being considered, and the associated credits that are being pursued by the project team. The credits presented here show potentially affected credits that would be seen in a standard construction project, though this may vary. The risk that the contractor is exposed to should be limited to the performance of these credits. The credits that affect the risk level of the contractor are outlined in Table 2-12.

Table 2-12. Total number of LEED-NC v2.2 credits that affect risk to the contractor. The prerequisite is included in the Sustainable Sites category.

Point Category	Point Total
Sustainable Sites	1 + 3
Water Efficiency	0
Energy and Atmosphere	0
Materials and Resources	13
Indoor Environmental Quality	6
Innovation and Design	2
Total Points Affected:	25

Risk to the Contractor

The risk related to compliance with these credits is generally passed on to the contractor from the owner in order to cover the potential costs to the owner that may stem from failure to achieve green certification. These potential damages can include the loss of a tenant or sale, loss of government incentives and tax credits, increased design and construction costs, rescinded donations on endowed projects, penalties on public projects with green mandates, increased energy and water costs over the life of the building, and diminished asset value (Anderson 2010).

Contract language. A major factor that must be considered is the amount of risk that is put upon the contractor by the owner or other parties. This is largely affected by the language that is included in the contract documents. While standard AIA documents are often used for construction projects, the green building movement is relatively new and some of these documents are insufficient. To avoid any confusion, there should be language or additional documents included in the documents that clearly defines the responsibilities for each party in relation to the area of green certification.

The association of risk with potential activities in the construction of a building is shown in Figure 2-2. Anderson et al. 2010 identified four areas that specifically affect the contractor on a construction project when green certification is desired. These are:

Performance specifications versus design specifications. The Spearin doctrine states that “[I]f the contractor is bound to build according to plans and specifications prepared by the owner, the contractor will not be responsible for the consequences of defects in the plans and specifications (248 U.S. 132, 1918).” This doctrine applies to design specifications and not performance specifications. In an

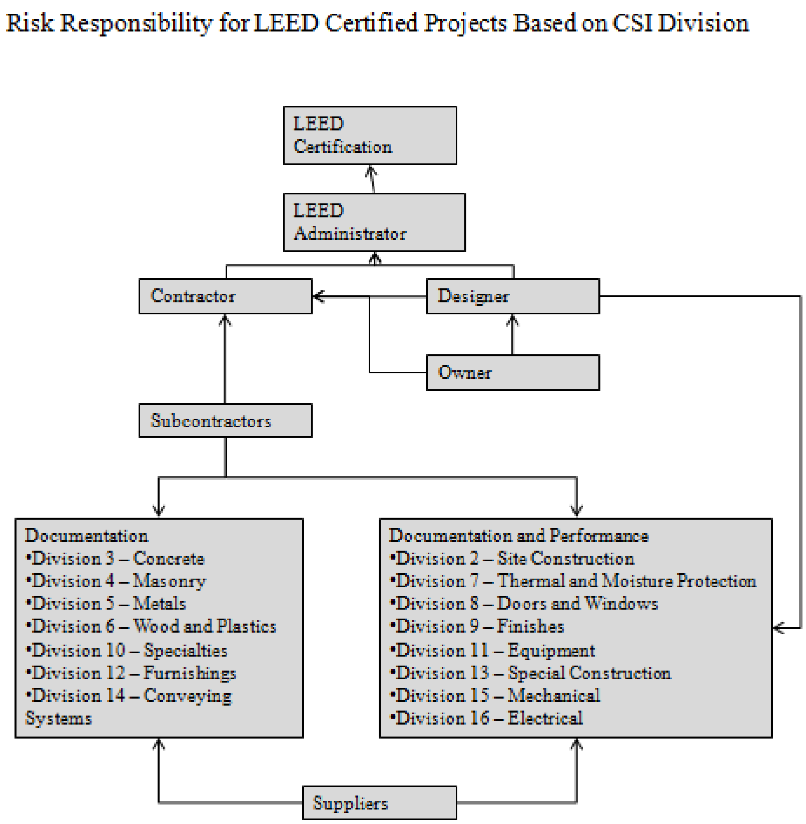

Figure 2-2. Display of the flow of risk associated with the construction of a LEED certified project.

area such as product selection for adhesives and sealants, under performance specifications the contractor would be responsible for selecting materials that were appropriate under SS credit 4, Low Emitting Materials. By accepting a contract with performance based specifications, the contractor would be accepting the responsibility for the design of this area of the project, and the resultant effects on the green certification. The risk associated would be bore entirely by the contractor.

Guaranteeing LEED certification. Generally, the contractor should at least be aware and probably cautious of guaranteeing LEED certification. The contractor in fact has little control over the certification in that very few of the LEED credits are under the control of the contractor. It is recommended that the contractor take appropriate responsibility for their portion of the project in a way that protects the owner's interests, but it is often unreasonable and unlikely for the contractor to assume all risk for the certification of the project (Anderson 2010).

Potential delays. There are components of a green building project that directly affect the schedule of the project, which falls squarely in the domain of the contractor. One issue stems from the popularity of green projects, and the availability of materials that are associated with these projects. Some of these products may be in high demand and low supply, which can present extended procurement times. Some of the LEED credits actually require more time to be included in the project schedule. Low-emitting paints associated with IEQ credit 4.2 generally take more time to cure, and may extend the time required for other activities. The building flush-out procedure that is associated with EQ credit 3.2 also has an associated time period that takes place following final construction activities, but prior to occupancy. This directly affects the critical path of the project as no other construction related activities may take place during this operation. This extra time may not be immediately quantifiable for a contractor, particularly one with limited experience in this arena, and presents a risk to the contractor of negatively affecting the schedule and any monetary penalties that are incurred related to these delays.

Green performance bonds. In certain locales, including Washington D.C., performance bonds are being utilized to ensure compliance with green mandates. If a building does not achieve LEED certification within two years after the issuance of the certificate of occupancy, the bond is forfeit. While the contractor may or may not be directly responsible for the performance mandated by this bond, they should be aware of the existence and consequences of this and the risk that is associated with non-compliance. The popularity of this type of performance bond should be monitored, as it will affect the latent risk that is posed to contractors undertaking projects where these are present.

The risks that are posed to a contractor due to the LEED certification system are outlined in Figure 2-3.

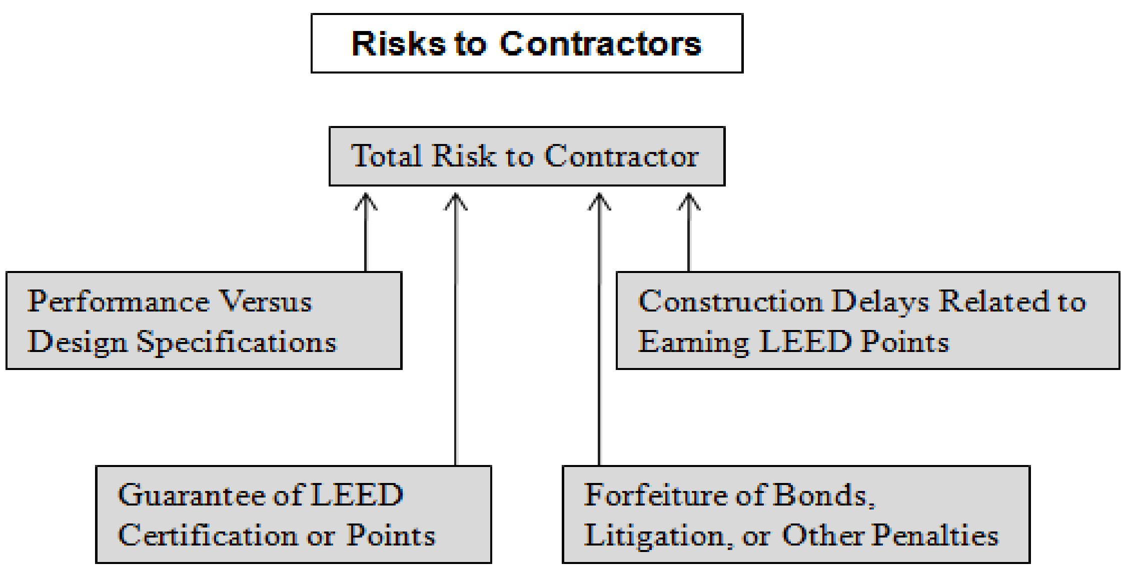

Figure 2-3. LEED related risks to contractors.

Contracts

Green building is becoming more common in the construction arena today, but there are still areas where the usual way of doing things is insufficient for the green building environment. Particularly the wording that is common in many standardized construction contract documents is insufficient. One particular example is the AIA A201 – 2007 General Conditions definition of “work.” This does not account for the requirement that contractors, subcontractors, and suppliers provide documentation that is essential to the LEED certification process. This documentation must be created and maintained throughout the project, and credits could be lost if this requirement is not performed (Anderson 2010). The AIA is providing documents that help to fill these gaps (such as AIA B101, B211, and B214), but holes still exist that may pose an increased risk to the contractor that they may or may not realize that they are subjecting themselves to.

Risk Analysis

The risk and potential costs appropriated by the contractor bidding on a construction project is a parameter that can be modeled and analyzed to gain insight into the decision of a contractor to increase price due to a perceived risk. The analysis of risk can also affect the decision of a contractor to bid on a certain project at all, affecting the number of bidders that may participate in the auction for a construction contract.

Analysis of risk and risk models are useful in that they allow us to obtain better insight and understanding about the problem at hand. This does not always equate to determining an exact scientific conclusion, but often creating a model that allows us some insight into the factors that we would like to control to achieve a more desirable outcome. This can be important in innovative construction projects since the “creative projects have to focus on risk management and risk management is the main consideration when managing creative projects (Alquien 1999).” Possible alternatives are often not clearly defined and analysis is used to help the decision maker to identify and explore possible alternatives and scenarios as well as to choose among them (Granger et al. 1990). James G March has defined this model in the following summary:

> Human beings make choices. If done properly choices are made by evaluating alternatives in terms of goals on the basis of information currently available. The alternative that is most attractive in terms of the goals is chosen. The process of making choices can be improved by using the technology of choice. Through the paraphernalia of modern techniques, we can improve the quality of the search for alternatives, the quality of information, and the quality of the analysis used to evaluate alternatives. Although actual choice may fall short of the ideal in various ways, it is an attractive model of how choices should be made by individuals, organizations and social systems. (March 1976)

Under this framework, we can use these models to provide an aid in the evaluation of different scenarios. According to Granger et al. (1990), a model can be used to assist in the “systematic exploration of alternative possible goals” by using a framework to identify existing and invent new alternatives to aid in reaching a that goal. The aim of this study is to understand how bidders in a construction auction develop a bid, based on risk and other factors, and to provide a tool for analyzing what goes into these bids.

The first step is to understand the source of the risk in the broadest sense. In this approach, there exists two types of risk; internal and external. These are described in Alquien (1999) and are described in detail in this report.

External Risk

External risk is a portion of total risk that the company does not control. External risk relates to factors in the environment that the company operates in such as; market shifts, government action, environmental (nature) interactions, market competition, and external regulation. External risk is also called market or environment risk.

Internal Risk

Internal risk represents the portion of total risk that is supposed to be under company control. Internal risk is associated with the technical solutions regarding products, processes, and resources. These can include new technology, required resources, innovative processes, and cost estimations.

Risk Balance

The risk balance of a company in regards to a specific project contains elements of both internal and external risk. The goal of a risk analysis is to evaluate the internal and external risks that have the potential to affect the company or project. These risks are outlined in Figure 2-4. The company must then decide whether these risks are acceptable, and if so at what level.

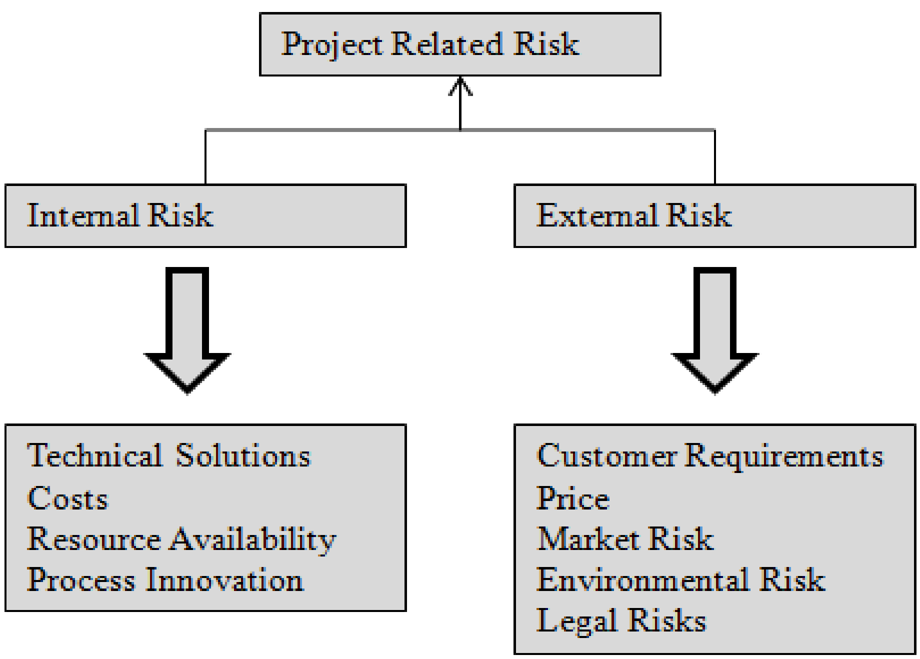

Figure 2-4. Elements of project related risk from Alquien 1999.

Levels of Risk

There are different levels of risk, and organizations and people are willing to accept varying levels of risk in the activities that they pursue. Every undertaking is associated with a certain level of risk and our decision to pursue this activity or not is based on our own risk acceptance policies.

Zero Risk

A zero-risk criterion is described as; independent of the benefits and costs, and of how big the risks are, eliminate, or do not allow the introduction of the risk (Granger et al. 1990). This describes the rationale that there is no reason for every policy to be accepted or every activity to be undertaken. Some activities will not be accepted because there is a risk involved, and the entity that is in the decision making position is unwilling to take on any associated risk. In the area of high-performance buildings and LEED certification, this is the equivalent of a contractor that is unwilling to even place a bid on a project because they are unwilling to accept any of the potential risk that is involved, no matter what the price. This may be due to the contractor having very limited experience in this type of construction, or a bidder that is very risk averse.

Approval-Compensation

Another criterion that is useful in describing levels of risk acceptance or aversion is the approval-compensation criterion. Under this model, one accepts risk or other costs to be imposed upon them in exchange for some sort of compensation in repayment for their inconvenience or potential losses. In the realm of sustainable construction, this refers to the cost increase that is included to recognize the risk in performing the project goals. This is one of the types of risk acceptance that will be useful in this study, since this is a quantifiable criterion that can be analyzed using a model that will be developed.

Examples of some alternative decision criteria that may be applied in risk management analysis (Granger et al. 1990) that are included in decision making, and will be useful in this study include several utility based criteria.

Utility Based Criteria

Utility criteria depend on the amount of risk that an entity is willing to accept and the amount of compensation that is required.

- Deterministic benefit-cost: Estimate the benefits and costs of the alternatives in economic terms and choose the one with the highest net benefit.
- Probabilistic benefit-cost: Same as deterministic benefit-cost but incorporate uncertainties and use expected value of resulting uncertain net benefit.
- Bounded cost: Do the best you can within the constraints of a budget that is the maximum budget the entity is prepared to devote to the activity.
- Maximize multi-attribute utility (MAU): This is the most general form of utility based criterion. Rather than use monetary value as the evaluation measure, MAU involves specifying a utility function that evaluates outcomes in terms of all their important attributes (including uncertainties and risk). The alternative with maximum utility is selected. Some of the Life-Cycle costing and other factors that are involved with sustainable construction would be included in this section, and could help to make a decision for an owner to spend more money to create a green building.
- Minimize chance of worst possible outcome: Political and behavioral considerations frequently dictate the use of such criteria.

These criteria are summarized in Figure 2-4.

Risk Criterion

In the environment of an auction, which a bidding environment is, contractors will utilize one or more of these decision criteria to make decisions regarding bids on projects perceived as risky. These decisions will be based on a hybrid type of risk criterion, since the process of construction bidding is very complex and involves many discrete factors and entities. Bidders will generally have either a risk seeking, risk neutral, or risk averse mentality, and based on this characteristic will place a value on the risk based on the size of the risk and the attitude of the bidder with respect to risk practices.

Table 2-13. Methods of dealing with risk and risk acceptance compensation policies.

Risk Practice	Choice Methodology
Deterministic Benefit-Cost	Choose option with highest net economic benefit
Probabilistic Benefit-Cost	Choose option with highest net economic benefit incorporating uncertainties and expected values
Bounded Cost/Risk	Choose best options while remaining within certain levels of cost/risk
Maximize multi-attribute utility	Choose option with highest total benefit
Minimize worst case	Choose least risky option

Different bidders will have different utility based decision making processes that they may make use of. This may depend on the characteristics of that particular bidder and the situation that the bidder is in at the time of the auction. A bidder is left to determine the benefits and costs of a decision, and when applied to LEED construction, the costs can be high to a bidder. Contractors may be required to deliver a building that is certified to a certain level, and this is likely to be stated in the contract documents. The contractor is then left with this obligation to fulfill. Assuming that the contractor is familiar with the LEED process, they may understand the costs that may be incurred. The contract language that is in place will generally describe the responsibilities of the contractor, and assign the risks that are involved to the interested parties. Some risks are specific to the contractor and the physical construction of the project. These may include (but are not limited to):

- Training costs: training to perform for certain LEED credits may be required including materials treatment under EQ credit 3.1 – Construction IAQ Management Plan, or training for processing and documentation of LEED.

- Equipment costs: new equipment may need to be purchased such as storage areas, cleaning machines, or pieces of machinery that are required for the installation of materials that are unfamiliar to the contractor.

On top of the costs that are expected to be incurred during the completion of a LEED project, there are also the costs that may be in addition to expected costs if the contractor is unfamiliar with the LEED process, or makes a mistake along the way. These include:

- Costs for appealing credits: There can be a significant cost associated with the failure to achieve credits that were targeted, particularly if these credits are required for the level of certification that is required

- Litigation: If a contractor fails to achieve the project standards that are outlined in the contract documents, then the owner may choose to recover money from the contractor to finish the project in a manner that meets the project requirements

- Documentation: If a contractor does not have the personnel or systems in place to provide the documentation that is required to successfully complete the certification of a building

These criteria are summarized in Table 2-14.

Table 2-14. Additional costs based on experience.

Experienced	Inexperienced (in addition to costs to experienced contractors)
Training Costs	Credit Appeal Costs
Equipment Costs	Litigation Costs
	Documentation Costs

Risk Factors

The first factor that will go into the model of a particular entities risk based decision is the level of risk (δ) that a bidder is willing to undertake. Entities exist on a scale that ranges from risk-averse (δ => 1) to risk seeking (δ => -1). Risk aversion refers to the proclivity to avoid risk as much as possible. These contractors may be willing to only undertake projects that they perceive as having very little or no risk. When LEED buildings are considered, this risk is assumed to be additional risk, on top of the normal amount of risk that is commonly associated with construction projects. The risk that will be considered in this study refers to the amount of additional risk that is perceived by the owner that is taken on above and beyond the risk associated with the normal business model of that entity.

A risk averse bidder may be reluctant to bid at all on a LEED project that they feel they is too risky for them. There are many reasons that a contractor may feel this way about a project. These include:

- The general risk aversion of the company – The company may feel that a LEED certified project presents more risk than they are willing to take on. This may vary from lower to higher levels of certification.
- The level of risk associated – The size of the project or the level of certification that is being pursued can have an effect. The amount of responsibility placed on the contractor in the construction documents can determine this level.
- The perceived risk based on internal factors – Company may not be familiar with LEED construction, or not have the necessary elements in place to properly deal with a given project.
- The perceived risk based on external factors – This could include other bidders, the state of the economy, location, or other risks apportioned to the contractor in the construction documents. Collectively referred to as the “bidding environment”.

This risk is compensated for is the amount of money that a contractor charges in addition to the profit that they are expected to make. This is a type of probabilistic benefit-cost. While contractors likely do not realize that they are performing this type of action, they probably are. This condition is described by adding a premium onto the project that is the result of the amount of risk perceived and the value of the project.

This study is concerned with construction costs and the risk preferences and values that drive those costs in a construction bid environment. The risk analysis is important in the early stages of the project (the bidding phase), because this is when uncertainty is the greatest. “Risk knowledge is fuzzy, distributed, unstructured, tacit, ancient history forgotten or transformed, insufficiently organized, not or completely cataloged, underestimated, registered in heterogeneous information systems, secretive, possessed by experts who are rare in the company (Alquien 1999).” There are certainly other costs and benefits associated with sustainable design and construction that should be considered, including operations and maintenance implications, user productivity and health, design and documentation fees, among other financial measurements (Mathiessen and Morris 2004), but the initial costs are the subject that will be more closely studied here. While each project must be studied individually, particularly if a higher level of certification is desired, there exists sufficient evidence to make generalizations about the costs associated with these projects which are becoming more and more commonplace. These projects are moving more from an innovative construction project to being the norm in the built environment today. Even buildings that do not seek any type of certification often use many of the same strategies as they make their way into building codes. Many owners also see the benefits financially from many of these strategies and wish to incorporate them into more of their projects.

Risk in Bidding

Much construction that is performed today is valued through a competitive sealed-bid auction. This is a type of auction that requires qualified bidders to submit sealed bids by a fixed deadline. The bid is then opened and the lowest price or second lowest price bidder is awarded the contract. The type of auction utilized in construction bidding generally involves both private and common value elements (Tang et al. 2006), though the auction is generally treated as a common value auction (Dyer 1996). This means that the bidders all have different estimates of the value of the project at the time that they bid, though the contract is generally believed to have the same value to each of the bidders. This valuation is based on the degree of uncertainty that is involved in the project, causing risk averse bidders to submit higher bids and risk seeking bidders to submit lower bids, with risk neutral bidders submitting bids in the middle. This arises from the manner in which bidders with different risk preferences consider the uncertainty.

Risk Compensation

Uncertainty always exists, but different bidders will view it under different lights. When a contractor faces a risk, the marginal utility of their income increases, leading to what is termed as precautionary bidding (Esö 2003). This has the effect of causing bidders to bid less aggressively since the value of each dollar of income is increased as compared to the value of winning the auction. A risk-averse (δ => 1) bidder would presume the uncertain factors to consist of a proportionately larger latent cost than latent profit. This indicates that a risk-averse bidder would perceive the uncertainties to contain a probabilistic negative profit.

The risk-seeking (δ => -1) bidders would view this scenario another way. The risk seeker would perceive the uncertainties involved in the project to be latent profit that can be realized, versus being a risk with the potential to result in a loss. This means that the risk-seeker believes that there is more profit in the project, and therefore is willing to submit a lower bid.

This indicates that the risk-seeking bidders are most likely to win the bid. This can have adverse consequences in several ways. The first is that the risk seeking bidder may also be increasing the latent risk of the bid seller. By selecting the riskiest bidder, the entity offering the bid is taking on increased risk. If the risk seeking bidder is then unable to perform the contract and cannot compensate for the loss, the seller/owner may be forced to accept the cost for the failure of the contract. The owner may be unknowingly accepting this risk and may be unwilling to do so.

If a very low bid is submitted, this could be an indication that this particular bidder is a risk-seeking bidder. There could be many reasons for this, including:

- Bidder may be struggling for work and is therefore willing to take on more risk or less return for a unit of work
- Economic conditions can have a significant effect, with many normally risk-averse bidders more willing to take on risk in a market that has less work
- Bidder may not understand the risks involved
- Bidder may have unseen barriers in place in case of failure that could affect the owner in the event that the bidder fails to perform.

Winners Curse

Another unintended consequence of accepting the lowest bid is that the low bidder faces an adverse selection problem as they only win when he/she has one of the lowest estimates of the cost of construction (Dyer 1996). If bidders are not careful to account for this adverse selection problem, then the low bidder may suffer from a "winner's curse", when the bidder wins the auction but the bid is so low that it results in a bid that delivers below normal or even negative profits. In a potentially risky scenario, such as the additional risk burden that is assumed in the construction of a LEED certified building, this is a type of risk that can be compensated for through the increase in the bid price that is tendered for the project.

The winner's curse is a phenomenon that has been well studied in the past. This phenomenon was first identified in an article often cited entitled "Competitive Bidding in High-Risk Situations" by Capen, Clapp and Campbell (1971). There were extreme discrepancies in the realized value of the early outer continental shelf (OCS) oil lease auctions that began in 1954 (Dyer 1996). Values of the fields were exaggerated by very aggressive bidders that were bidding on items that had a value that was very difficult to define. Bidding spiraled out of control and some winning bidders found themselves in possession of oil field leases that provided very small if any returns for their initial investment. Similar claims have been made regarding auctions for book publication rights, in professional baseball's free agency market, and in corporate takeover battles (Dyer 1996). This outcome has proven to be pervasive even in a laboratory environment.

In a study conducted by Dyer et al. in 1989, it was shown that even sophisticated bidders, drawn from a pool of executives in the construction industry, suffered extensively from the winner's curse. The 1989 study results showed that over 50% of the bids that were submitted (in the laboratory) were below the expected value conditional on winning the auction, so that half of the bids resulted in negative expected profit. This is a concern, because the owner that is asking for these bids may be unknowingly hiring a bidder that has put themselves in a position where the project is not going to be profitable for them.

Risks Associated with the Winner's Curse

The winning bidder is likely to not be pleased with the negative profit scenario that is associated with the winner's curse in winning the auction. This is a dangerous position for both the winning bidder and the bid seller. The bidder may choose to not perform on the contract or may choose to try to make up for the lost profit through change orders or other means. Both of these scenarios will result in a higher than expected cost to an owner. This final cost may even be larger than some of the higher bids that were rejected, but were likely more responsible bids.

Another potential out for a bidder that has fallen victim to the winner's curse is the withdrawal of the bid due to arithmetical errors. In most states there exist laws that allow bidders to withdraw their bids without penalty (without loss of bid bond) if they believe that they have errors included in the bid. The interpretation of these errors can be quite broad (Dyer 1996). While intended to include clear arithmetical errors that can occur, this can also be an out for a bidder that has made a mistake in generating a bid that is too low. There are some reasons that are given by owners that explain why they would allow a broad interpretation of these errors. The owner does not want a contractor working for them that has submitted a bid that is so low that they will certainly lose money on the job. A survey by Dyer and Kagel in 1996 developed some of the reasons that were given that owners would allow a bid to be withdrawn:

- To preserve the relationship between the contractor and the owner
- To prevent damage to the contractor by forcing completion of the contract that could result in disruption to the job schedule
- Forcing forfeiture of bid bonds can result in the reduction of the number of bids on subsequent bids, causing an increase in the bid prices submitted based on bid models

The resulting problems that occur from accepting performance on a bid that is too low can result in effects on the owner and project that are similar to the effects of the winner's curse on the bidders. Risk seeking bidders can therefore have a widespread effect on the auction, the project, and even subsequent auctions.

Identifying the Winner's Curse

One possible way to identify the winner's curse in the auction environment is the quantification of the difference between the lowest and the second lowest bid. This is commonly referred to as "money left on the table". This is money that the lowest bidder could still have collected and still have been the lowest bid. As the number of bidders (*n*) increases, bid amounts decrease, and the money left on the table should decrease also. The relationships are outlined in Table 2-15.

Table 2-15. Percentages of bid based on the difference range of bids tendered. Values derived from Dyer et al. 1996, page 1466.

n:	4	7	12
Mark-up needed to prevent winner's curse	60.0%	75.0%	84.6%
Expected Profit	40.0%	25.0%	15.4%
Money left on table	10.0%	3.6%	1.3%

Contractors are generally aware of at least the effect of these factors, and make up for these deficiencies through increases in the bid price. The key findings of Fu et al.'s 2002 study was that inexperienced contractors, largely without expertise and being wary of the winner's curse, would submit higher bids in bidding. This is included in the bidding model that is proposed in Tang et al. 2006, and is presumed to be included in the contractors bid. This price increase is a result of the risk aversion policies of the contractor, and the contractor's perceived risk associated with that particular project. Through examination of the winner's curse and money left on the table, we can then determine:

- How the number of bidders affects the bid price and competition among bidders
- How the lowest bidder brings increased risk not only to themselves, but also to the bid seller.

Experienced Bidders

The experience of the bidder that is submitting the bid also has an effect on the bid price that is offered. The Fu et al. study of 2002 found that contractors who bid more frequently are more competitive than contractors that bid occasionally. While this serves to reflect in the overall bid strategy of the contractor, the effect was much stronger in construction work that was more standardized. While much of the work that is related to LEED construction is not considered standard yet, much of the work is repeatable from project to project. This would infer that the more LEED contracts that a contractor bids on, the more competitively priced that these bids will become. Construction experience can be considered as the synthesis of five components that apply to bidding as well, since bidding is seen as an integral part of the construction process (Fu et al. 2002):

1. Managerial experience
2. Technological experience (construction methods)
3. Costing experience
4. Local experience (trade practice, legal environment, etc.)
5. Institutional experience (knowledge of client's preferences, etc.)

These components are roughly equivalent to the types of the internal and external risks that the contractor faces that are outlined in Figure 2-4. The experience of the contractor in fact is a mechanism that allows the contractor to better deal with the risks that are presented to them. As is discussed in this report, risk can be seen as either an opportunity for profit or loss. Experienced contractors have learned to limit their exposure to the downside of this risk, and the bids that they tender reflect the reduction of this uncertainty.

The Fu et al. study of 2002 concluded that the bidding performance of less experienced contractors is likely to be more erratic in terms of competitiveness. Following this logic, the more experienced that a contractor is, the more likely they are to bid not only competitively but also consistently.

Risk and HPB

There is an increased risk that is associated with constructing HPBs. This is particularly true with a building certification requirement under a system such as LEED, where a building can be considered a failure if it does not achieve the level of certification that is required by the owner. This risk is associated with a cost that is passed on to the owner by inclusion of a mark-up on the bid price which can be called a "LEED premium." The actual cost of this is often the first concern of an owner or other parties involved. Inexperienced bidders will likely have a less accurate estimation of the risk involved and the profits available, and are therefore more likely to overcompensate for a potential winner's curse, raising the bid price in response to this risk.

Bidding Model (Tang et al. 2006)

Tang et al. 2006 developed a model that takes into account many of these the factors that are commonly referred to as the bid climate, including the risk tendencies of a particular bidder. The basic models of bidding when related to construction projects assume that a buyer (bidder) purchases a single item from sellers in a one-shot auction. The number of bidders (n) and the probability distribution of bidders' private information are assumed to be common knowledge. In the traditional model all bidders are also considered to be risk neutral (problems with this assumption are addressed in the Tang et al. 2006 bid model).

The Tang et al. 2006 formula differs from the standard bidding model in one important way. The standard bidding model assumes that all bidders are risk averse, while this is untrue in the low-price bids that are applied in the construction setting. In an auction bidding environment, the bidders may all have different risk preference tendencies and will all compete for the same contract. This differs from the first assumption of the standard bidding model that states:

- All bidders are risk neutral

The Tang et al. 2006 study sets up a model that allows for the variance in the bidders risk preferences of the various bidders. Other assumptions that will be made and are taken from the standard bidding model are:

- Every bidder has the independent information of estimating the bid
- Payment is just the function of the price quoted
- The distribution of bidders' price quoted is symmetric

Model Factors

In the modified model, the number of bidders is denoted as n. These bidders are all assumed to be qualified to bid for the project in question. All of the bidders in the auction may have a different value of the project denoted by c_i. These different valuations are all assumed to be independent and drawn from the same distribution of private values denoted by distribute function F on interval [c_l , c_h], $c_l = \min\{c_i\}$, $c_h = \max\{c_i\}$ ($i = 1,2,3, \ldots,n$), c_i is a private value that is known only to bidder i. The cost c_i is assumed to be estimated by bidders that are risk neutral, and therefore is not influenced by uncertain factors.

The estimation of risk is defined as bidder *i*'s estimation for uncertain factors and is denoted as $\overline{c}_i$. The value of $\overline{c}_i$ and the degree that it influences the valuation c_i depend on the risk preferences of the bidder i. Thus the valuation of c_i is made up of three parts: first is c_i affected by positive $\overline{c}_i$, second is c_i affected by negative $\overline{c}_i$, and third is c_i not affected by $\overline{c}_i$, representing the differing risk preferences of the bidders. So the payment to the bidder from the owner would be noted as:

$$p_i = c_i + \delta\overline{c}_i \tag{2-1}$$

Where p_i denotes the payment to bidder *i*, $\delta \in [-1,1]$, represents the bidder *i*'s risk taking preference with three cases;

- $\delta \in [-1,0)$, δ presents risk seeking bidders degree of seeking risk
- $\delta \in (0,1]$, δ presents risk averse bidders degree of avoiding risk
- $\delta = 0$ indicates that the bidder is risk neutral

Therefore, if the assumptions of the model are true, then the bid price valuation b_i submitted by bidder *i* can be represented by:

$$b_i = c_i + \frac{(c_h - c_i)}{n} + \frac{n-1}{n}\delta\overline{c}_I \tag{2-2}$$

This model is an extended bidding model that considers the bidders' risk preferences. The number of bidders lowers the price that is submitted, as the auction becomes more competitive. Bidders may also be aware of the rise in the number of bidders and their bid may reflect this. The model in equation (1) takes this into account but at the same time makes the value of the perceived risk and the risk preferences of the bidder distinct. In this model, the bidder *i* who submits the lowest price b_i will win the bid in the lowest price sealed bid construction auction. If the bidder is risk neutral then $\delta = 0$ and the quote price is equal to:

$$b_i = c_i + \frac{(c_h - c_i)}{n} \tag{2-3}$$

This model (3) is nearly identical to the standard bidding model.

If the bidder i is risk seeking, then $\delta \in [-1,0)$. When δ approaches -1, the suggestion is that the bidder will lower their price so as to win the construction contract by increasing their degree of risk seeking δ.

If the bidder is risk averse, then $\delta \in (0,1]$. As δ approaches 1, the bidders will tend to increase their bid price. The bidders hope to win the bid, but increase the risk based on the amount of risk perceived.

The number of bidders (*n*) brings into effect two competing forces that change as the number of bidders increases (Dyer 1996). Since *n* is assumed to be known to all of the bidders involved, the bids are directly affected by this. As *n* increases, strategic factors promote lower bids, since any chance of perceived profit is contingent on winning the auction. The heightened awareness of adverse selection that occurs with the decrease in bid price competes with the strategic factors to form the function of the assumed equilibrium distribution that exists in the auction. Though there is evidence that the bid price initially decreases with respect to *n*, the expected winning bid is expected to decrease as *n* increases throughout (Dyer 1996). This phenomenon is exemplified in Figure 5-1.

The conclusions of this model are that in a lowest price, sealed bid auction for a construction project, risk averse bidders will tend to quote a higher price, risk seeking bidders will submit a lower price, and risk neutral bidders will quote a price in the middle of the two. The risk seeking bidders are therefore more likely to win the bid for the construction project.

CHAPTER 3
METHODOLOGY

The aim of this study is to create a model that identifies and quantifies the perceived risks that are associated with LEED construction. This will be done by creating a spreadsheet that utilizes the Tang et al. model, location factors, information from the GSA 2004 and Davis Langdon 2004 and 2007 studies and knowledge of risk practices and the LEED process.

Standard Building Characteristics

This is the cost of construction that is related to a project that is not seeking LEED certification. This is used to establish a base price for the project bid. This information is generated from a database of costs generated by EVstudio and RSMeans and found on-line (EVstudio 2010). These costs reflect the cost of educational facilities and was generated using April 2010 RSMeans information providing a cost for college classrooms, college dormitories, college student unions, and college laboratories. The cost was provided for each of the building types in many locations throughout the United States. The data that was generated by EVstudio is provided in Figure 3-1, Figure 3-2, Figure 3-3, and Figure 3-4.

The square foot costs of the buildings are extremely varied, and the particular type of building and location of the structure must be considered before the analysis. These calculations are for use as an example only and costs that are associated with a particular project should be used if the model is to be applied to a particular situation. It should be noted that these costs are used to generate a cost for a specific area of the country and will be later adjusted to reflect the type of demographic location that the actual structure is located in.

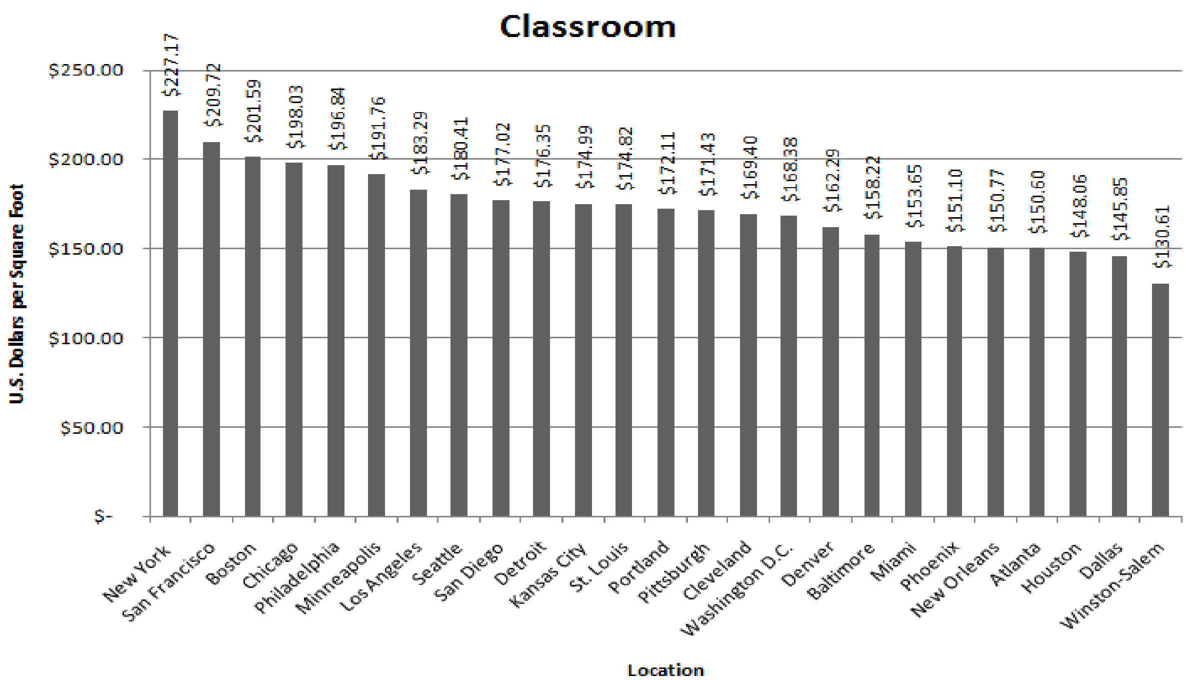

Figure 3-1. Cost per square foot of college classroom facilities generated by EVStudio 2010 from RSMeans data April 2010.

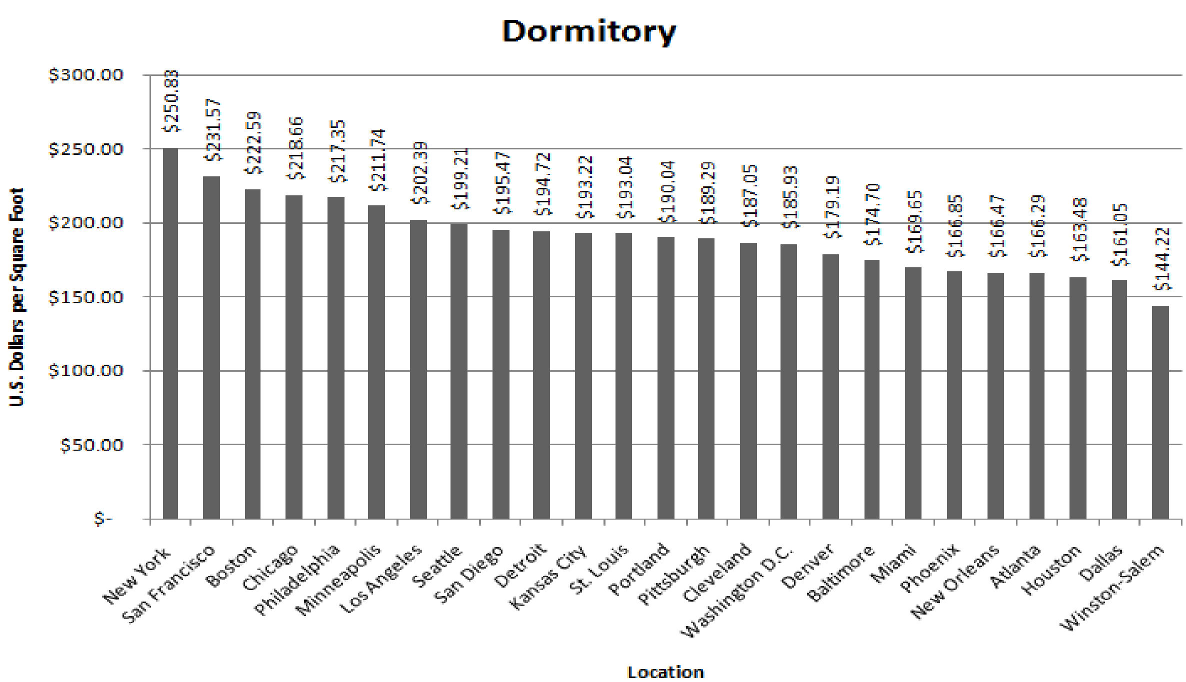

Figure 3-2. Cost per square foot of college dormitory facilities generated by EVStudio 2010 from RSMeans data April 2010.

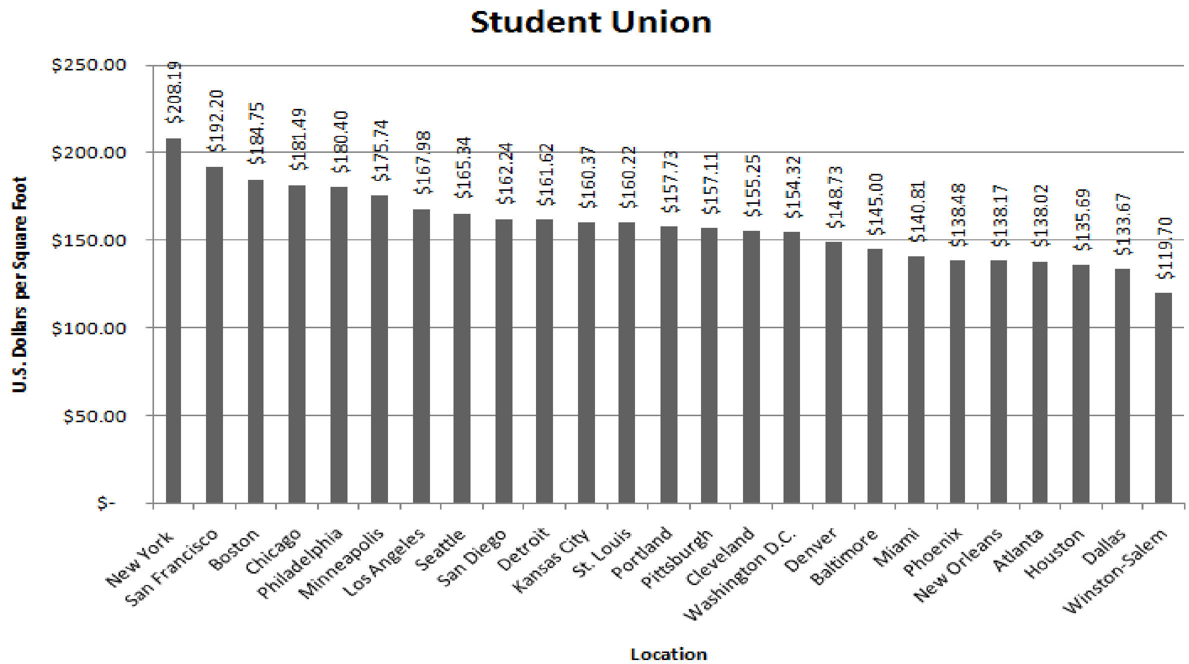

Figure 3-3. Cost per square foot of college student union facilities generated by EVStudio 2010 from RSMeans data April 2010.

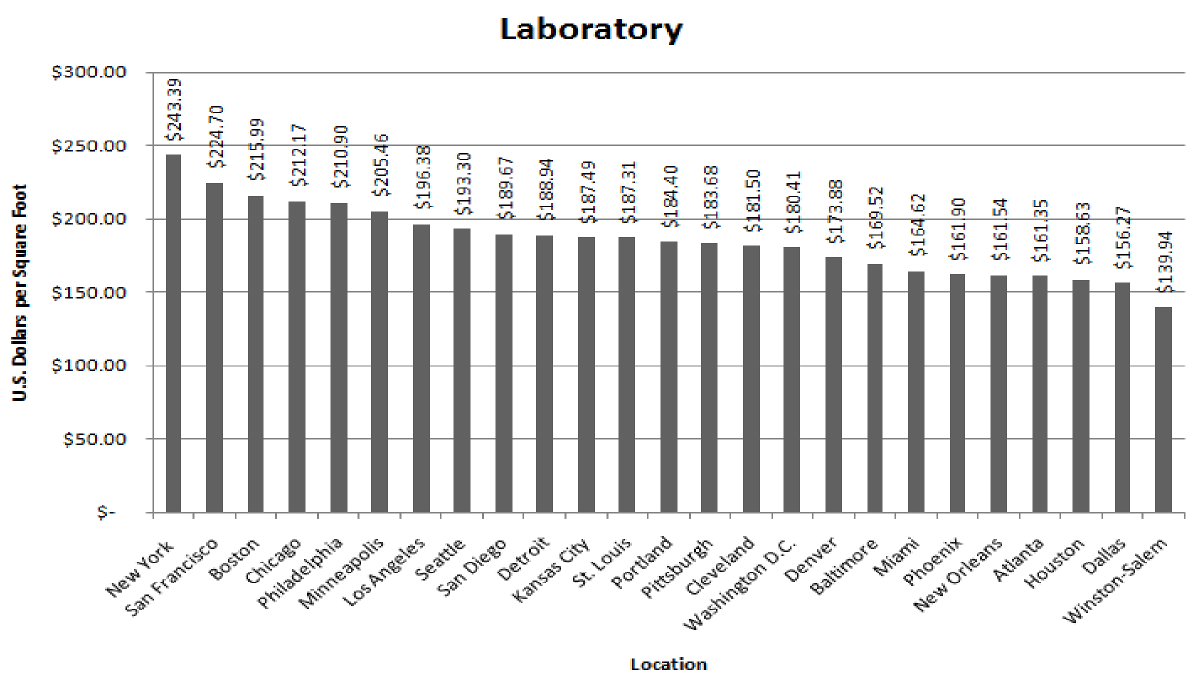

Figure 3-4. Cost per square foot of college student union facilities generated by EVStudio 2010 from RSMeans data April 2010.

Level of Certification

The level of LEED certification that is desired will have an impact on the level of risk to the contractor and therefore the value of the bids submitted for the construction of the project. The values that will be used are based on the average cost premiums of LEED certified projects as a percentage increase of the contract price. These premiums were collected from the 2004 GSA cost study and are displayed in Table 3-1

Table 3-1. Percentage increases in cost of LEED certification from GSA 2004 study.

Level of LEED Certification	Maximum% Markup (Based on GSA Study)	GSA Data Range
Certified:	1.00%	-0.4% to 1.0%
Silver:	4.40%	-0.03% to 4.4%
Gold:	8.10%	1.4% to 8.1%

Platinum level certification was not included in the 2004 GSA study or the table above because the platinum level of certification requires an extraordinary level of performance to attain the required point level. A percentage increase is included in the model but is only applicable if the appropriate factors are known to an extent for the model to be useful. These factors can be very project specific and without specific information fall outside of the scope of the framework for the purposes of this model.

The information in the GSA study is used to produce the model, and is not required for proper analysis. The GSA study was used because of the extent of data that was available in the study, which was useful for developing the model. The results of this study are certainly not appropriate for all scenarios. The percentages shown in Table 3-1 can be changed to fit any particular scenario without adjusting the model. The percentages in Table 3-1 are used to establish a baseline for the perceived uncertainty and may be adjusted to fit a particular project but should be accompanied with other data inputs that are consistent with that particular scenario.

Soft Costs

There are two types of costs that are represented in the increase in costs that are seen in the construction of a LEED certified building (Northbridge 2003). These costs are construction costs and soft costs. Soft costs are costs that are not directly related to the construction of the building, but are necessary and in addition to original building estimates. These costs are outlined as percentages in Table 3-2.

Table 3-2. Estimates of LEED related soft costs derived from the Northbridge Environmental report 2003, p. 6.

Cost Category	Estimated %	Range
Design Costs	0.5%	0.4% - 0.6%
Commissioning	1.0%	0.5% - 1.5%
Documentation and Fees	0.7%	0.5% - 0.9%
Energy Modeling	0.1%	0.1%
Total	2.3%	1.5% - 3.1%

*For GSA data, use : 0.25%

The soft costs are considered part of the cost in achieving LEED certification, but do not represent an increase in the cost to the contractor, except for a portion of the documentation costs, and will therefore be subtracted from the total estimated LEED mark-up for the project. The information that is supplied by the GSA study, when used in the model, will reflect a lower percentage of soft costs since much of this additional work is already included in the cost estimates. Subtracting the soft costs will allow the analysis of only the costs associated with the direct construction costs of the building.

Risk Aversion

The risk aversion segment of this model will be based on the auction model developed by Tang et al. 2006. This model is defined as:

$$b_i = c_i + \frac{(c_h - c_i)}{n} + \frac{n-1}{n}\,\delta\overline{c}_i \qquad (2\text{-}2)$$

where:

- b_i = expected bid from contractor *i.*
- c_i = bidder *i*'s perceived value of a project – the common value of the auction, or the base line construction estimate as provided by RSMeans.
- c_h = expected value of the high bid – described as twice the bidder's perceived risk to represent a worst case bidder.
- *n* = number of bidders – determined by a base case number further refined by the appropriate adjustments.
- δ = risk behavior of contractor ***i*** – determined by the risk aversion behavior of the particular contractor.
- $\overline{c}_I$ = perceived risk to contractor ***i*** – product of the base price of the project, an expected cost of LEED certification as determined in the GSA 2004 study to represent LEED related risk in excess of the standard building risk, and the Experience Factor.

Perceived Value; c_i

The perceived value of the project is assumed to be the cost of the construction that is related to the project based on the RSMeans estimate that was described in "Standard Building Characteristics". Based on the Davis Langdon studies of 2004 and 2007, there is no measureable difference in the average value of a standard building and the value of a LEED certified building. Following this, the value of the project to the contractor should not be more than the estimated construction costs of the project. LEED related costs are expected to be "extra" costs that are a factor of the LEED Premium that is placed on general construction tasks due to the increased risk. Assuming that this value is the same for all bidding parties defines the designation of a "common value" auction, meaning that all bidders will receive the same benefit from winning the contract. There is some debate as to whether this definition fits a construction auction exactly, but for the purposes of modeling, this assumption must be made.

High Bid; c_h

Research on bid ranges showed that bid results can vary wildly dependent on a variety of factors, and there is little data on predicting what a high bid will be. To set a baseline for the model, the high bid is set to the perceived value, representing a scenario in which all of the bids submitted at the same price, therefore not affecting other bids. For the example project scenario the high bid is assumed to be the base cost of the building, c_i, plus twice the expected mark-up as related to certification level defined in Table 3-1. This provides an ample range for bid prices, without disabling the model. In a specific situation, the owner that is putting this contract out would generally have an accurate representation of this number. For the purposes of the model, this number only needs to be predicted to demonstrate the behavior of the other variables.

Number of Bidders; n

The number of bidders (n) is entered as an expected value that is then adjusted for several environmental factors collectively referred to as the “bidding environment”. The initial number of expected bidders would have to be determined from historical precedence that would be specific to the type of project that is being constructed. For the purposes of normalizing this model, a base case of 10 expected bidders was used. This number decreased as the level of certification increased as shown in Figure 3-6. This number would then be adjusted for economic conditions as described by the bidding climate and economic factor.

Bidding climate/economic factor. The strength of the economy at the time of the auction will affect the number of bids that are submitted. This phenomenon is described in the “LEED Associated Risk” section and is determined using the data in Table 3-3. The economic factor is multiplied by the number of bidders expected under normal conditions to simulate a reduction in n during stronger economic times or an adverse bid climate. If the number of bidders is known previous to the construction of the model, this factor can be ignored, but determination of the number of bidders is important to the accuracy of the model, and should be adjusted accordingly to match the expected bidding environment.

Table 3-3. Economic factor multipliers for the base case of the risk model.

Bid Climate	Factor
Very Restricted Climate	0.50
Restricted Climate	0.75
Stable Climate	1.00
Open Climate	1.25
Very Open Climate	1.50

Risk Behavior; δ

The risk behavior of a particular contractor must be identified and entered into the model. This factor will be different for each particular contractor, and may vary with time. This factor is more clearly defined in the section titled “Risk”. This factor is defined directly from the chart in Table 3-4 and entered into the model. This factor represents the risk-aversion behaviors of the contractor that is bidding on the project. “Very risk averse” would mean that the contractor has a strong aversion to taking on any additional risk, while a “Very risk seeking” bidder would be willing to take on more risk in a project. This factor is applicable to the current project only, and may differ for the same contractor when considering other projects.

Table 3-4. Table for determination of the risk factor for a particular contractor.

Risk Policy	Factor
Very risk averse	1.0
Somewhat risk averse	0.5
Risk Neutral	0.0
Somewhat risk seeking	-0.5
Very risk seeking	-1.0

Experience

The experience in bidding and construction for a particular contractor will have an effect on the bid that is submitted. The factors that are used to define the Experience Factor for a specific contractor are shown in Figure 2-9. This factor is used to represent the amount of experience that a certain contractor has in a specific type of construction. In this case the contractor’s experience would be experience with LEED certified projects, though experience with general construction relative to the project would play a part in determining this factor. This factor may also vary among the levels of LEED certification. If a contractor had extensive experience in LEED certified buildings but had never constructed any building higher than LEED Silver, the experience factor may be less if the certification level desired is Gold or Silver. An experience level of 1 represents an average level of experience in the type of project being considered. The potential values shown in Table 3-5 reflect potential values, but does not represent the limits of these values.

Table 3-5. Determination of experience factor for a specific bidder, relative to a specific project.

Experience Level	Factor
Very Experienced Bidder	0.90
Experienced Bidder	0.95
Average Experience	1.00
Very Little Experience	1.15
Inexperienced Bidder	1.30

Experience will be related to the particular project with a specific contractor. LEED related projects often pursue varying strategies for achieving points, and experience with a strategy in the past could have an effect on the experience of the contractor. Experience with a certain level of certification could also affect this value. Location could also play a part, if the contractor has performed multiple projects in the location and is familiar with the local requirements and conditions.

Location

The results from the model and the inputs must be subjected to a further adjustment for the location of the project. From the Tang et al. (2006) model there is determined what will be called a “LEED Uncertainty Cost”. This is the amount of extra cost that would be added onto the original building price for the total in the contractor’s bid. The final adjustments that must be made for this price are:

Proximity to services. The Davis Langdon study of 2004 determined that there are benefits from having a project in an urban setting. This phenomenon is examined in depth in the “Cost of LEED” section of this study. The factors in Figure 2-10 are used to reflect the effect of demographic location on the expected bid price. These factors are specific to this example, as extraordinary conditions may exist for a specific project. This could occur if the project is located in an area that is particularly capable of providing services or infrastructure that is beneficial to the LEED rating system. It should be noted that locations exist where LEED is impossible to attain or is prohibitively expensive. This model assumes that neither of these conditions exist and that there are no extremely adverse conditions that occur that limit the feasibility of the project.

Table 3-6. Factors for determining costs related to the proximity to urban centers. Data derived from Mathiessen and Morris 2004

Proximity to Services	Factor
Very urban location	0.50
Somewhat urban location	0.75
Suburban location	1.00
Somewhat rural location	1.25
Very rural location	1.50

Climate factor. The climate that a project is located in also has an effect on the amount that LEED certification will cost. The additional cost associated with the climate that a project is located in is defined in the Davis Langdon study of 2004. The results of that study are shown in Table 3-7.

Table 3-7. Percentage increase in LEED costs as related to climate. Data derived from Mathiessen and Morris 2004.

Location	Certified	Silver	Gold	Platinum
Mild Coastal	-	1.00%	2.70%	7.80%
California Central Valley	-	3.70%	5.30%	10.30%
Gulf Coast	-	1.70%	6.30%	9.10%
Northeast Coast	-	2.60%	4.20%	8.80%
Rocky Mountain	-	1.20%	2.80%	7.60%
Average Increase:		2.04%	4.26%	8.72%

The percentages shown in Table 3-7 are increases in LEED costs over standard construction costs and are related to energy use, cost of energy, temperature fluctuations and relative humidity.

Location factor. The two factors related to the location of the project have been combined into what will be called the Location Factor. The factor is the product of the proximity multiplier and the percentage increase defined in Table 3-7 as the Climate Factor. The table shown in Table 3-8 shows the result of this calculation. The column for Location Factor is the result of subtracting the Location Percentage Increase from the Average Location Increase and multiplying the result by the Proximity Factor.

Table 3-8. Calculations for Location Factor.

Certification Level	Location % Increase*	Proximity Factor	Average Location Increase	Location Factor
Certified	-	0.00	0.00%	0.00%
Silver	2.04%	0.00	2.04%	0.00%
Gold	4.26%	0.00	4.26%	0.00%
Platinum	8.72%	0.00	8.72%	0.00%

Assumptions

The Davis Langdon (2004) study outlined seven factors that affect the cost of LEED certification. Of the seven the first three will be used to calculate expected bids using the model described. These three factors are:

1. Demographic Location
2. Bidding Climate and Culture
3. Climate

Assumptions are made involving the remainder of the factors listed in the Davis Langdon (2004) study. These remaining factors are assumed to be true and constant.

4. Project owners and team members are fully invested in the certification of the building

5. The goals of certification are outlined sufficiently earlier in the project to avoid any negative effects, and the design is as fully developed at time of bidding as is normally expected

6. The size of the building only affects the overall cost of the building and systems, and the relative cost is unchanged over a reasonable range of costs and building size

7. Point synergies will be used to all possible effect for each given project. This will be different for each building, and would be impossible to predict for a general sampling.

For the purposes of this model, factors 4 -7 are assumed to be normal and average. This does not indicate that this is the case in all construction projects. These factors are likely to be variable in a real world scenario, but to make this model effective and valid these must be assumed so that heterogeneity of the data may be preserved. For this reason the factors will be divided into five categories. The first three categories will represent 3/5 of the LEED/Risk Premium, with the final four categories representing 2/5 of the LEED/Risk Premium as ghost categories that are assumed to not affect the amount of perceived risk for the purposes of this model.

Calculations

The factors and costs that were addressed in "Modeling Factors" will be used to calculate the risk based LEED costs and bid amounts. The flow of the calculations is outlined in Figure3-5, and the spreadsheet form is shown in Figure 3-6.

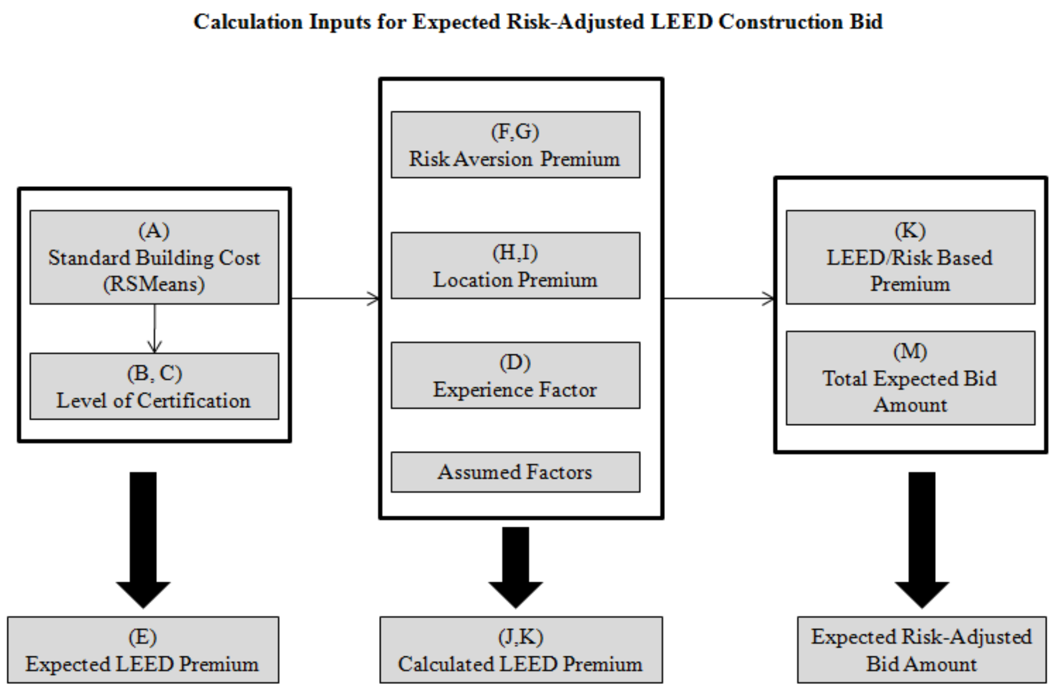

Figure 3-5. Interactions of the factors and costs associated with the calculation of LEED premium.

Calculation Table

The calculations are listed by column as follows from Table 3-9:

A. Base Cost – This is the cost of the building without any LEED certification. This is generated from RSMeans and is adjusted for the project location.

B. Certification Level – This is the level of LEED certification that is desired. This is defined as Certified, Silver, Gold, and Platinum.

C. Average LEED Risk % - This is the average LEED percentage markup that was found in the GSA (2004) study. This value is applied to the Base Cost as a baseline value and to provide inputs for other equations including high bid and perceived risk.

D. LEED Uncertainty – This is the cost increase that is expected to be seen based on the cost of a standard building, the level of certification that is desired, and the experience level of the contractor submitting the bid.

E. Risk Aversion Factor – This is the factor that is described by the Tang et al. (2006) risk model. This model takes into account the perceived value of the project, the expected number of bidders, the expected high bid, the perceived risk to the contractor, and the risk tendencies of the contractor. The factor is defined as the difference ratio of the expected bid price to the perceived value of the contract.

F. Risk Aversion Premium – The premium, in dollars, that is a result of the increase of the bid price using the Risk Aversion Factor. This is a portion of the total increase in the cost found in Column K. This factor is assumed to make up 80% of the value of the total increase found in Column K.

G. Project Location Factor – This factor is related to the difference of the cost of LEED certification in different geographical locations.

H. Location Premium – The premium, in dollars, that is added to the base price of the building to achieve LEED certification. This is a factor of the total LEED risk price and is assumed to make up 20% of the total increase found in Column K.

I. Experience Factor – This factor is determined from the table shown in Figure 25 and is entered directly into the spreadsheet. This value may differ for different levels of certification.

J. Calculated LEED Premium % - This is the increase, in percentage, that is observed from the calculated LEED/Risk based premium and the Base Cost of the building.

K. Calculated LEED Premium – This is the total result of the calculations including the Risk Aversion Premium, the Location Premium, and the Experience Factor. Represents the total cost increase over the Base Cost that is expected.

L. LEED Premium Baseline – Value of LEED costs when no other factors are included. Represents the average current cost of LEED construction and is used as a baseline to compare other calculations.

M. Total Expected Project Cost – The base cost of the project plus the anticipated LEED/Risk Based Premium.

N. LEED Related Soft Costs – Calculated at 1.6% of the construction costs. This cost represents the soft costs that are not directly bore by the contractor.

O. LEED Based Increase in Construction Costs – Represents the increase in costs that can be expected over the standard costs of a building.

P. Total Risk Adjusted Bid Price – Value of the bid that can be expected to be submitted by contractor i for the given LEED certified project.

Table 3-9. LEED Premium and Bid Amount calculation table.

From Table 2		From Table 3 Column B	A x C x I (or Entry x I)	Table 9 Column H	0.8 x D x E	From Table 12	0.2 x D x G	From Table 7
A	B	C	D	E	F	G	H	I
Base Cost	Certification Level	Average LEED Risk %	Perceived LEED Uncertainty	Risk Aversion Factor [-1,1]	Risk Aversion Premium ($)	Project Location Factor [-1,1]	Project Location Premium ($)	Experience Factor
$	Certified	1.00%	$	0.00%	$	0.00%	$	0
$	Silver	4.40%	$	0.00%	$	0.00%	$	0
$	Gold	8.10%	$	0.00%	$	0.00%	$	0
$	Platinum	12.00%	$	0.00%	$	0.00%	$	0

K/A	(F + H) x I	A + D	A + K	Table 13 Value x A	K - N	A + O
J	K	L	M	N	O	P
LEED Premium %	LEED/Risk Based Bid Premium	Value Using Average Risk Scenario	Total Expected Project Cost	Soft Costs	Additional LEED Related Construction Costs	Total Bid for Construction Costs
0.00%	$	$	$	$	$	$
0.00%	$	$	$	$	$	$
0.00%	$	$	$	$	$	$
0.00%	$	$	$	$	$	$

CHAPTER 4
ANALYSIS

To represent the method of using the model developed in this study, an example will be used for demonstration. A baseline scenario will be conducted to verify the accuracy of the model, and then an analysis of the input factors will be performed.

Example Project

Project

This project will be a college classroom in Atlanta, Georgia. This building will encompass 55,000 square feet and will be evaluated for potential costs related to LEED certification. The project is located in a dense urban area. The project is expected to occur during a time of strong economic growth, with an open bidding environment.

Bidder

The model proposed is sensitive to the specific properties of the bidder. The bidder is a large company that is rated very risk averse. The bidder has relatively little experience in LEED related projects.

Analysis

Base Price

The base price of the structure, in Atlanta, Georgia, is calculated using the RSMeans tables. Calculated value is $8,283,000.00

Level of Certification

Table 3-1 shows the expected (average) costs for the corresponding level of LEED certification. These factors are based on the 2004 GSA study and are appropriate for this type of building. All of the factors will be applied to demonstrate the use of the model. It should be noted that for this example, the highest cost estimations will be used from the GSA 2004 study.

Table 4-1. Expected LEED costs for example 55,000 square foot classroom in Atlanta, GA with a base value of $8,283,000. Maximum mark-up amounts will be used for the example. Values based on GSA 2004 data.

	From GSA or Enter Value		Table 2 value x B	Table 2 value + C
A		B	C	D
Level of LEED Certification	% Markup (Based on GSA Study)		Additional Perceived Risk Premium	Total Expected Building Cost
Certified:	Max	1.00%	$82,830	$8,365,830
	Min	-0.4%	$(33,132)	$8,249,868
Silver:	Max	4.40%	$364,452	$8,647,452
	Min	-0.03%	$(2,484)	$8,280,515
Gold:	Max	8.10%	$670,923	$8,953,923
	Min	1.4%	$115,962	$8,398,962
Platinum*:	Max	12.00%	$993,960	$9,276,960

*No data exists in the GSA 2004 study for Platinum level certification.

Baseline Case

First, an analysis showing the average or expected value of the project with the associated LEED certification scenarios. In this case, all variables will be set to the assumed average default value to validate the accuracy of the model. The results of this analysis are shown in Table 4-2. In the baseline case, the expected bids and costs are equal to the increases that are expected to be observed. This reflects an average scenario that does not take into account the specific factors associated with a particular project and contractor. From this analysis it can be shown that the expected total costs are as follow in Table 4-3 and 4-4. The relationships between the expected and standard costs are outlined and reflect the calculations in the model.

Note that the expected cost of the structure is equal to the calculated cost as shown in Table 4-2, and the expected values in Table 4-3. This shows that the model is

Table 4-2. Calculation of costs in the baseline scenario.

From Table 2		From Table 3 Column B	A x C x I (or Entry x I)	Table 9 Column H	0.8 x D x E	From Table 12	0.2 x D x G	From Table 7
A	B	C	D	E	F	G	H	I
Base Cost	Certification Level	Average LEED Risk %	Perceived LEED Uncertainty	Risk Aversion Factor [-1,1]	Risk Aversion Premium ($)	Project Location Factor [-1,1]	Project Location Premium ($)	Experience Factor
$8,283,000	Certified	1.00%	$95,254	1.13%	$77,067	0.00%	$19,050	1.15
$8,283,000	Silver	4.40%	$419,119	5.13%	$352,507	-0.51%	$83,396	1.15
$8,283,000	Gold	8.10%	$771,561	9.90%	$678,356	1.02%	$155,886	1.15
$8,283,000	Platinum	12.00%	$1,143,054	15.20%	$1,053,438	0.19%	$229,045	1.15

K/A	(F + H) x I	A + D	A + K	Table 13 Value x A	K - N	A + O
J	K	L	M	N	O	P
LEED Premium %	LEED/Risk Based Bid Premium	Value Using Average Risk Scenario	Total Expected Project Cost	Soft Costs	Additional LEED Related Construction Costs	Total Bid for Construction Costs
1.16%	$96,118	$8,378,254	$8,379,118	$20,550	$75,567	$8,358,567
5.26%	$435,904	$8,702,119	$8,718,904	$21,344	$414,559	$8,697,559
10.07%	$834,243	$9,054,561	$9,117,243	$22,209	$812,033	$9,095,033
15.48%	$1,282,483	$9,426,054	$9,565,483	$23,120	$1,259,363	$9,542,363

Table 4-3. Determination of baseline analysis.

Certification Level	Base Cost	LEED Average	Calculated	LEED Increase Compared to Average: $ Difference	% Difference
Certified	$8,283,000	8,378,254	$8,379,118	$ 863.64	0.01%
Silver	$8,283,000	8,702,119	$8,718,904	$ 16,784.35	0.19%
Gold	$8,283,000	$9,054,561	$9,117,243	$ 62,681.65	0.69%
Platinum	$8,283,000	9,426,054	$9,565,483	$ 139,429.73	1.48%

Table 4.4. Determination of baseline analysis.

Certification Level	Base Cost	LEED Average	Total Project Increase Compared to Non-LEED: $ Difference	% Difference
Certified	1.00%	1.16%	$ 96,118.14	1.16%
Silver	4.40%	5.26%	$ 435,904.15	5.26%
Gold	8.10%	10.07%	$ 834,243.10	10.07%
Platinum	12.00%	15.48%	$ 1,282,483.73	15.48%

capable of predicting the baseline scenario when all of the variables are set to assumed normal conditions. There is no difference in the calculated values versus the expected values. The effects of the changes to these variables are all based on this scenario, to more easily determine the effects of the changes of certain conditions. Following the establishment of this baseline, the variables associated with the specific case will now be input.

Bid Climate

The climate of the bidding pool and environment must be determined. These factors are described using the Economic Factor (Table 4-5) to determine the number of bidders and the Experience Factor (Table 4-6) to determine perceived risk in the final analysis. The economic factor affects the number of bidders, and the experience factor affects the perceived risk to the contractor. Heightened experience levels result in a lower perceived risk.

Table 4-5. Economic factor determination will result in the selection of 0.75 reflecting a strong external economic condition and restricted bid environment.

Climate Description	Factor
Very Restricted Climate	0.50
Restricted Climate	0.75
Stable Climate	1.00
Open Climate	1.25
Very Open Climate	1.50

Table 4-6. The determination of the Experience Factor will result in the selection of a factor of 1.15.

Experience Level	Factor
Very Experienced Bidder	0.70
Experienced Bidder	0.85
Average Experience	1.00
Very Little Experience	1.15
Inexperienced Bidder	1.30

The number of bidders is assumed to be 10 in an ideal environment. The Economic Factor and the Level of Certification are used to adjust this number based on the bidding environment as shown in Table 4-7.

Table 4-7. Determination of the number of bidders.

Level of Certification	Expected # of Bidders	Bid Climate Factor	# of Bidders
Certified	10	0.75	8
Silver	8	0.75	6
Gold	6	0.75	5
Platinum	5	0.75	4

Risk Aversion

The example bidder is described as very risk averse, which will result in an elevated Risk Aversion Factor. A Risk aversion factor of 1.0 has been selected to correlate with the determination that the bidder is very risk averse. This will serve to elevate the effect of the amount of perceived risk involved in the project. The determination of this factor is shown in Table 4-8.

Table 4-8. Determination of bidder's Risk Aversion Factor. A factor of 1.0 has been selected to represent the example scenario.

Description of Bidding Entity	δ
Very risk averse	1.0
Somewhat risk averse	0.5
Risk Neutral	0.0
Somewhat risk seeking	-0.5
Very risk seeking	-1.0

Using the Tang et al. 2006 model and the inputs that have been derived thus far the amount of the bid based on uncertainty can be determined as shown in Table 4-9.

The Tang et al. 2006 risk model is defined as:

$$b_i = c_i + \frac{(c_h - c_i)}{n} + \frac{n-1}{n}\delta\overline{c}_i \qquad (2\text{-}2)$$

where:

- b_i = expected bid from contractor i
- c_i = bidder i's perceived value of a project
- c_h = expected value of the high bid
- n = number of bidders
- δ = risk behavior of contractor i
- $\overline{c}_i$ = perceived risk to contractor i

Table 4-9. Risk Aversion calculation using the model described in Tang et al. 2006.

Level of Certification	Perceived Value	Expected Bid Value	Risk Aversion Factor
Certified	$8,283,000	$8,376,874	1.13%
Silver	$8,283,000	$8,708,194	5.13%
Gold	$8,283,000	$9,103,017	9.90%
Platinum	$8,283,000	$9,542,016	15.20%

Location

The location of the project is in Atlanta, Georgia, which will be considered a gulf coast location for the purpose of using the Davis Langdon 2004 location adjustments. The appropriate Proximity Factor has also been selected to represent the fact that the project is located in a downtown urban location. The combination of these factors is defined in Table 4-10.

Table 4-10. Adjustment factors for location of the example project.

Certification Level	Location % Increase*	Proximity Factor	Average Location Increase	Location Adjustment
Certified	-	0.50	0.00%	0.00%
Silver	1.70%	0.50	2.04%	-0.51%
Gold	6.30%	0.50	4.26%	1.02%
Platinum	9.10%	0.50	8.72%	0.19%

The Location Adjustment represents the aggregate effects of the Location Increase and the Proximity to Services. The observed negative value under the Certified level scenario shows that due to the location of the project, the cost is less than the average increase that is expected.

Soft Costs

Soft Costs represent the value of the costs that are not directly related to the construction of the project. Since this example is using the GSA costs for analysis, most of these costs are included in the price increase, and can be left out. The increase in soft costs for the GSA analysis result in an increase of 50 cents per square foot, or 0.25% of the per square foot cost. The result will be a soft cost value of 0.25% that will represent the cost of Documentation and Fees. This cost will be used since it is also applicable in an institutional environment such as a college campus. Many institutional entities use the same type of standards that the GSA uses, and these calculations are more appropriate. Since this project related to a school campus the data from the GSA study is appropriate. This will vary for each scenario, but for this example it will be assumed that the institution in question is using standards similar to the GSA including requiring commissioning, and minimum energy performance. This cost is quantified in Table 4-11, and is expressed as a percentage of the overall costs of the construction project. Note that in the GSA study this is calculated as a per square foot cost.

Table 4-11. Estimated Soft Costs. 0.25% will reflect GSA data.

A	B	C
Cost Category	Estimated %	Range
Design Costs	0.5%	0.4% - 0.6%
Commissioning	1.0%	0.5% - 1.5%
Documentation and Fees	0.7%	0.5% - 0.9%
Energy Modeling	0.1%	0.1%
Total	2.3%	1.5% - 3.1%

Enter Soft Costs: 0.25%

Expected Costs

The results of the analysis are shown in Table 4-13.

Results

This example highlights the effects of the decision to pursue LEED certification on the expected overall and construction costs of the project. The increase that is shown in the example is greater than the baseline case due to the following factors:

- High risk aversion factor
- Decreased number of bids due to the effects of the bidding climate
- Increased costs due to the lack of experience of the contractor

The results of the calculations in the example case are highlighted in Figure 4-12.

Table 4-12. Comparison of baseline case to example scenario.

LEED Increase Compared to Average	
$ Difference	% Difference
$ 863.64	0.01%
$ 16,784.35	0.19%
$ 62,681.65	0.69%
$ 139,429.73	1.48%
Total Project Increase Compared to Non-LEED	
$ Difference	% Difference
$ 96,118.14	1.16%
$ 435,904.15	5.26%
$ 834,243.10	10.07%
$ 1,282,483.73	15.48%

Table 4-13. Results of model calculations using the example scenario showing the costs of LEED certification.

From Table 2		From Table 3	A x C x I (or Entry x I)	Table 9 Column H	0.8 x D x E	From Table 12	0.2 x D x G	From Table 7
A	B	C	D	E	F	G	H	I
Base Cost	Certification Level	Average LEED Risk %	Perceived LEED Uncertainty	Risk Aversion Factor [-1,1]	Risk Aversion Premium ($)	Project Location Factor [-1,1]	Project Location Premium ($)	Experience Factor
$8,283,000	Certified	1.00%	$95,254	1.13%	$77,067	0.00%	$19,050	1.15
$8,283,000	Silver	4.40%	$419,119	5.13%	$352,507	-0.51%	$83,396	1.15
$8,283,000	Gold	8.10%	$771,561	9.90%	$678,356	1.02%	$155,886	1.15
$8,283,000	Platinum	12.00%	$1,143,054	15.20%	$1,053,438	0.19%	$229,045	1.15

K/A	(F + H) x I	A + D	A + K		K - N	A + O
J	K	L	M	N	O	P
LEED Premium %	LEED/Risk Based Bid Premium	Value Using Average Risk	Total Expected Project Cost	Soft Costs	Additional LEED Related Construction Costs	Total Bid for Construction Costs
1.16%	$96,118	$8,378,254	$8,379,118	$20,550	$75,567.71	$8,358,567
5.26%	$435,904	$8,702,119	$8,718,904	$21,344	$414,559	$8,697,559
10.07%	$834,243	$9,054,561	$9,117,243	$22,209	$812,033.80	$9,095,033
15.48%	$1,282,483	$9,426,054	$9,565,483	$23,120	$1,259,363	$9,542,363

Sensitivity Analysis

A sensitivity analysis has been performed to demonstrate how the LEED related costs change as the inputs are altered. The purpose of the model is to be able to see the relationships between the variables that affect the costs of LEED construction, and a sensitivity analysis will help to highlight these effects.

A sensitivity analysis was conducted and the results are shown in Figures 4-1 to 4-7. This analysis will help to evaluate the effects and relationships that are involved in the model. The supporting data is found in Appendix A.

Certified Level Building

The analysis of this building is shown in Figure 4-1. The most sensitive factor of the ones that are depicted here is the risk aversion factor. Proximity to services has no effect as this was the result of the Davis Langdon (2004) study. The strength of the economy had the predicted effect of increasing costs as the economy became stronger. This is due to the increased risk aversion of the bidders and the resultant decrease in the number of bidders that are willing to submit a bid on the project. This effect is small, as predicted for a Certified level project, since the perceived risk of this level of certification is relatively small.

Silver Level Building

The analysis under the Silver level of certification is shown in Figure 4-2. The most sensitive factor of the ones that are depicted here is the risk aversion factor. Proximity to services has a small effect as this was the result of the Davis Langdon (2004) study. The strength of the economy had the predicted effect of increasing costs as the economy became stronger. This is due to the increased risk aversion of the bidders and the resultant decrease in the number of bidders that are willing to submit a bid on the project. This effect is small, as predicted for a Silver level project, since the perceived risk of this level of certification is relatively small, but is noticeably larger than the effect of the economy that was seen in the Certified level project. This is due to the higher level of risk that is associated with the higher level of certification.

Gold Level Building

The analysis of the Gold level certified building is shown in Figure 4-3. The most sensitive factor of the ones that are depicted here is the risk aversion factor. Proximity to services has a small effect as was the result of the Davis Langdon (2004) study. The strength of the economy had the predicted effect of increasing costs as the economy became stronger. This is due to the increased risk aversion of the bidders and the resultant decrease in the number of bidders that are willing to submit a bid on the project. This effect is larger, as predicted for a Gold level project, since the perceived risk of this level of certification is relatively large, and is noticeably larger than the effect of the economy that was seen in the Certified and Silver level projects. This is due to the higher level of risk that is associated with the higher level of certification. The additional risk results in a lower number of bidders that are willing to compete for the project, and this is increased as the economic condition strengthens.

Platinum Level Building

The analysis of the Platinum level building is shown in Figure 4-4. The most sensitive factor of the ones that are depicted here is the economic factor, surpassing the effects of the Risk Aversion Factor. Proximity to services has a small effect as was the result of the Davis Langdon (2004) study. The strength of the economy had the predicted effect of increasing costs as the economy became stronger. This is due to the increased risk aversion of the bidders and the resultant decrease in the number of bidders that are willing to submit a bid on the project. This effect is very large, as predicted for a Platinum level project, since the perceived risk of this level of certification is large, and is noticeably larger than the effect of the economy that was seen in the other levels of certification. This is due to the higher level of risk that is associated with the highest level of certification. The additional risk results in a much lower number of bidders that are willing to compete for the project, and this is amplified as the economic condition strengthens.

Risk Aversion

The analysis of the effect of risk aversion is shown in Figure 4-5. Increases are relatively small for the lower levels of certification since the perceived risk to the contractors is small. Since the risk is small, even the most risk averse contractors do not place a large additional premium on the construction costs. This condition changes as the level of certification rises. As higher levels of certification are pursued, the amount of risk to the contractor is increased. For risk-seeking contractors, this has less of an effect than that seen with the risk-averse contractors. As the perceived risk, and the risk-aversion of the contractor increases, the total effect on the cost of the project begins to amplify more quickly. This effect would be more pronounced if the perceived risk is increased, or the contractor has a higher level of risk aversion.

Number of Bidders

The analysis of the effect of the number of bidders is shown in Figure 4-6. This effect increases as the level of certification that is being pursued is increased, due to the level of risk that is associated with the level of certification. Larger numbers of bidders has the effect of heightened competition which drives down the cost of the project. When put into the model, the effect of having a very small number of bidders increases steeply as the certification level rises. If a project has a small number of expected bidders, the owner should take actions to increase the number of bidders. This could be accomplished by lowering the level of certification as shown in this figure.

Experience

The analysis of the amount of experience that the contractor has is shown in Figure 4-7. This demonstrates the amount of the increase in LEED related costs are a function of the perceived risk of the contractor and the amount of experience that the contractor has in that particular type of building. As experience increases, perceived risk diminishes and becomes part of the standard cost. This has the effect of removing the volatility of the price increase since the additional costs are no longer affected by the risk policies of the bidder. This accurately reflects the limited experience that contractors have with higher levels of LEED certification and the large cost increases that are associated with these projects.

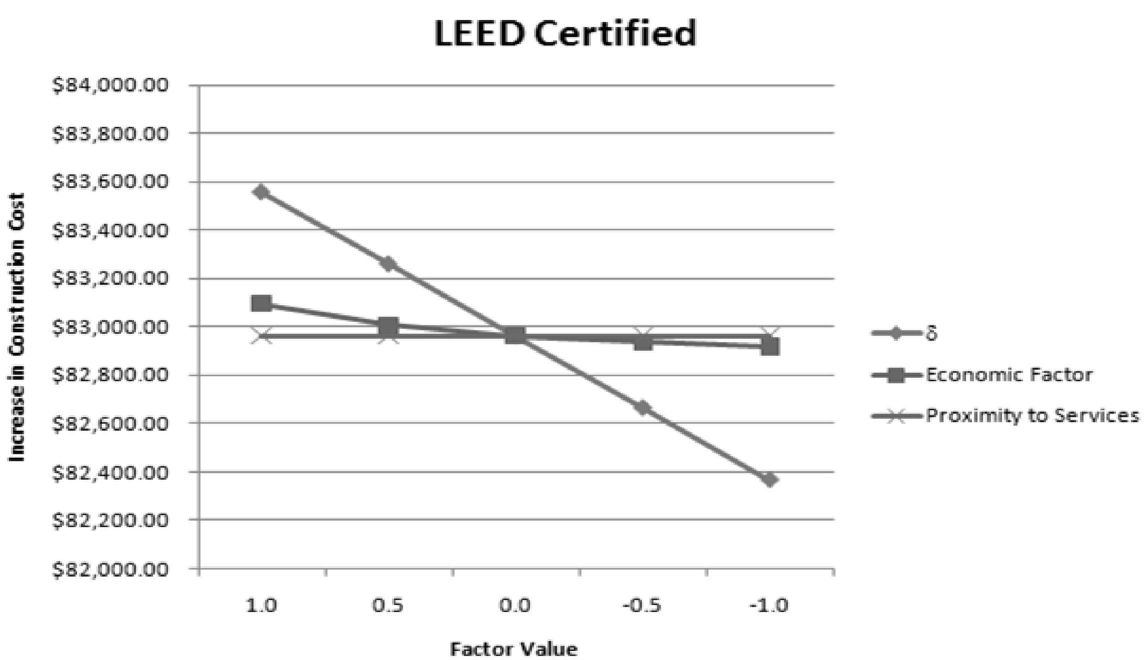

Figure 4-1. Graphical representation of the effects on certain variables on the LEED associated increase of construction costs on a Certified level building.

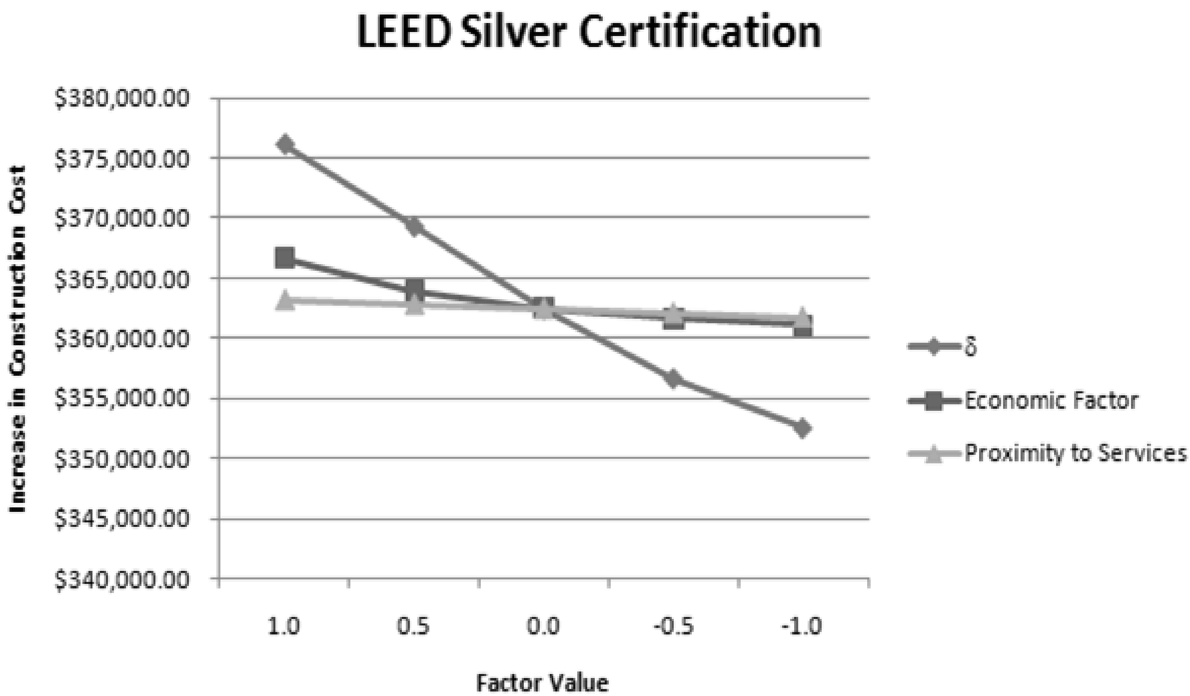

Figure 4-2. Graphical representation of the effects on certain variables on the LEED associated increase of construction costs on a Silver level building.

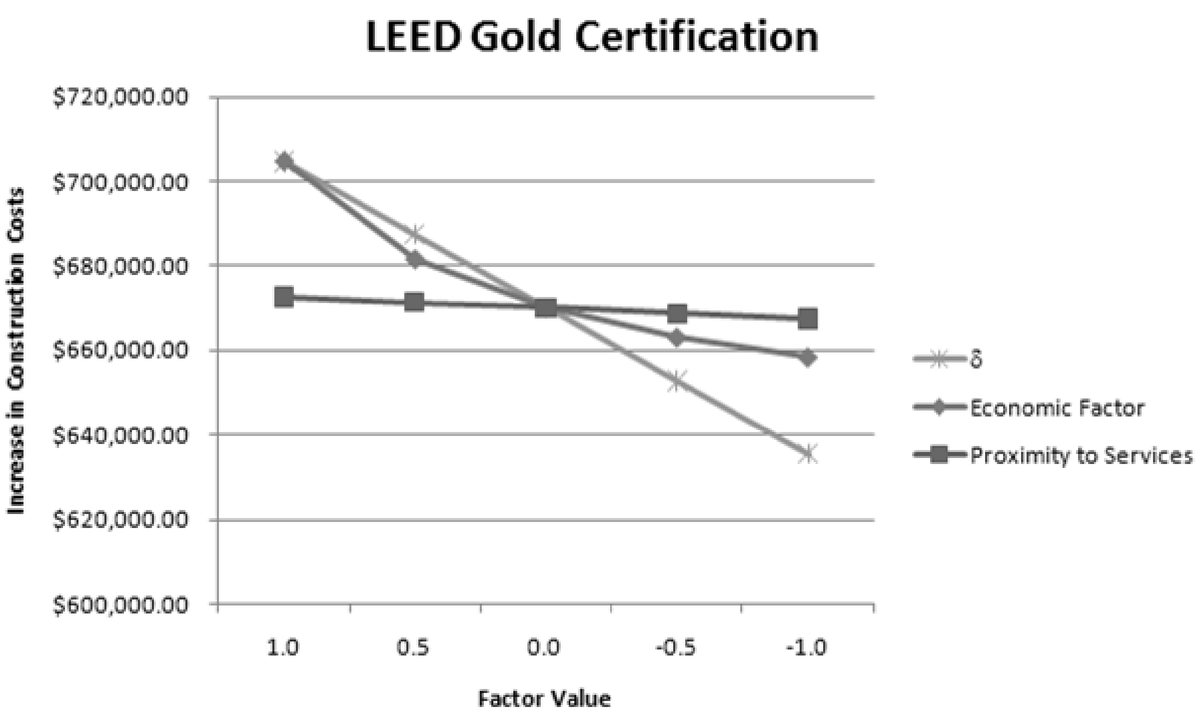

Figure 4-3. Graphical representation of the effects on certain variables on the LEED associated increase of construction costs on a Gold level building.

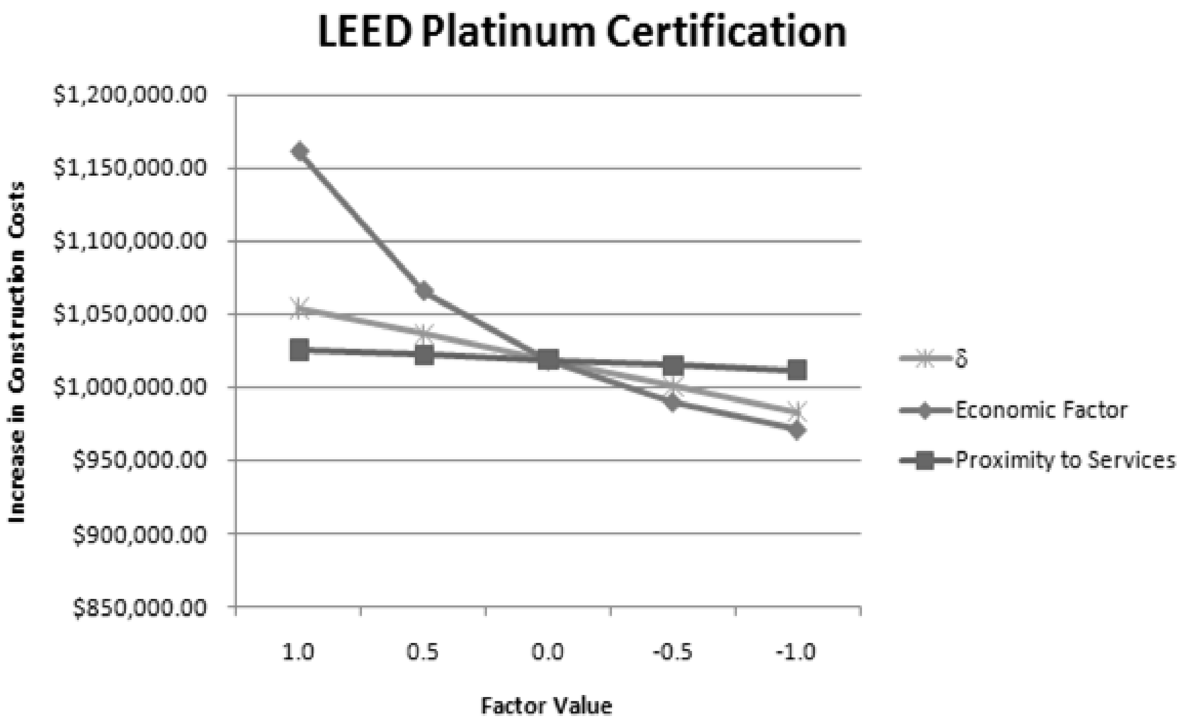

Figure 4-4. Graphical representation of the effects on certain variables on the LEED associated increase of construction costs on a Platinum level building.

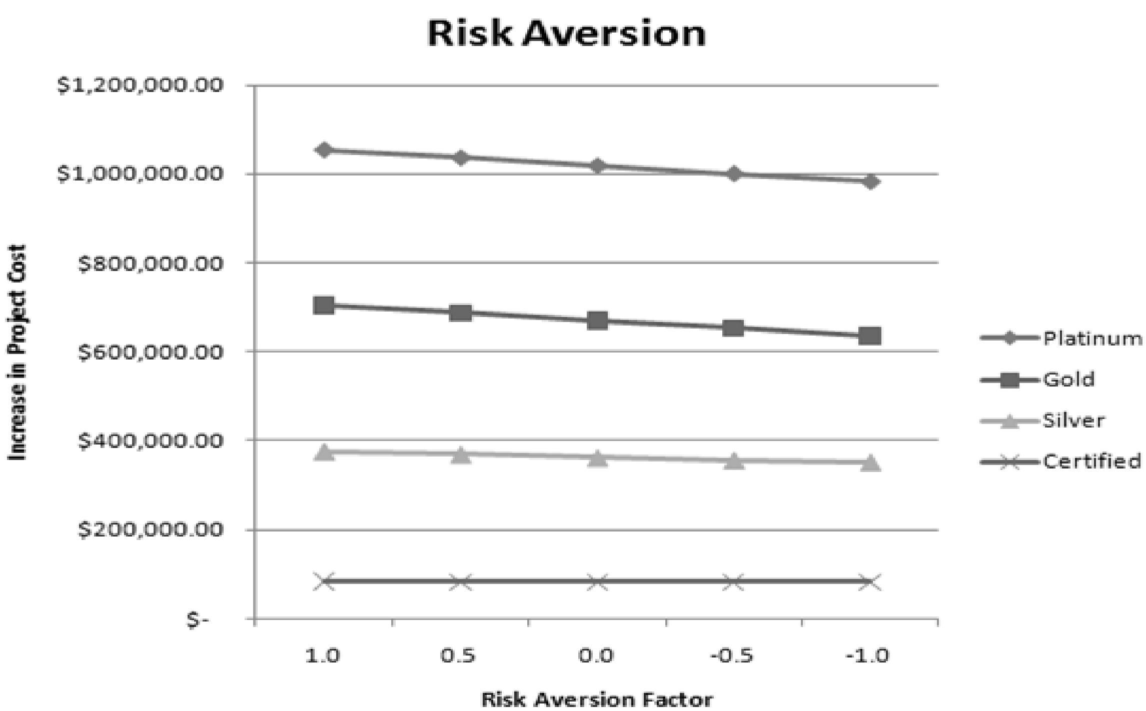

Figure 4-5. The effects of various risk aversion behaviors on the additional cost of LEED construction.

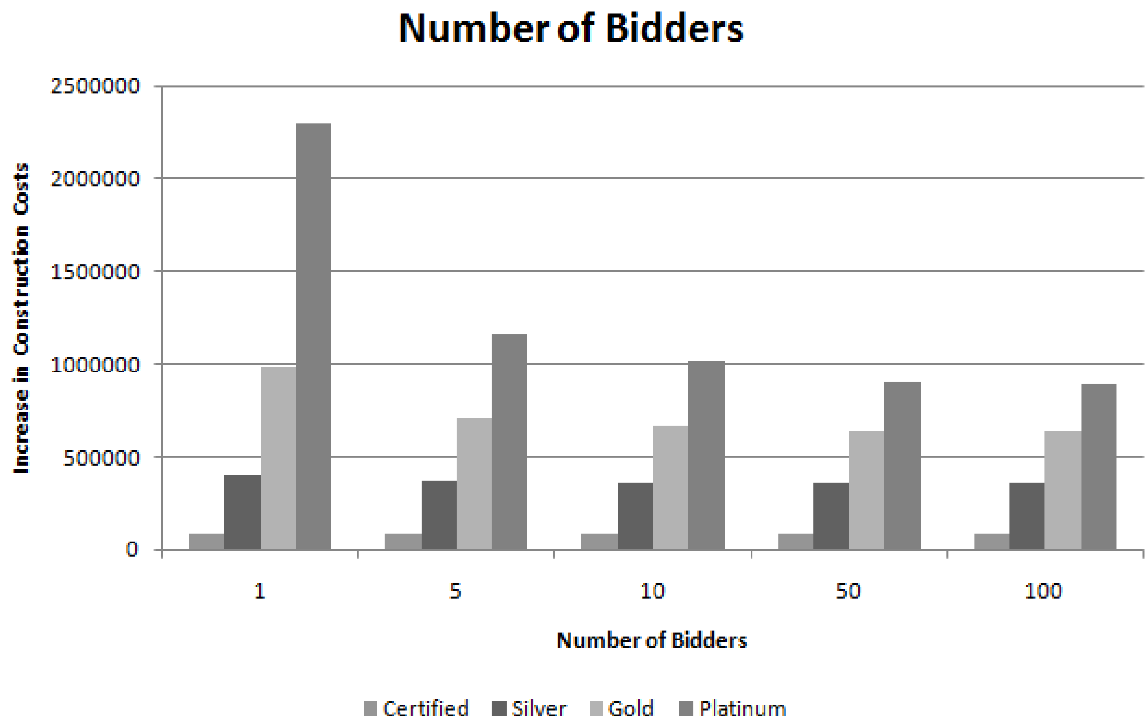

Figure 4-6. The effect of the number of bidders has a definite effect on the increase in construction costs of a LEED project.

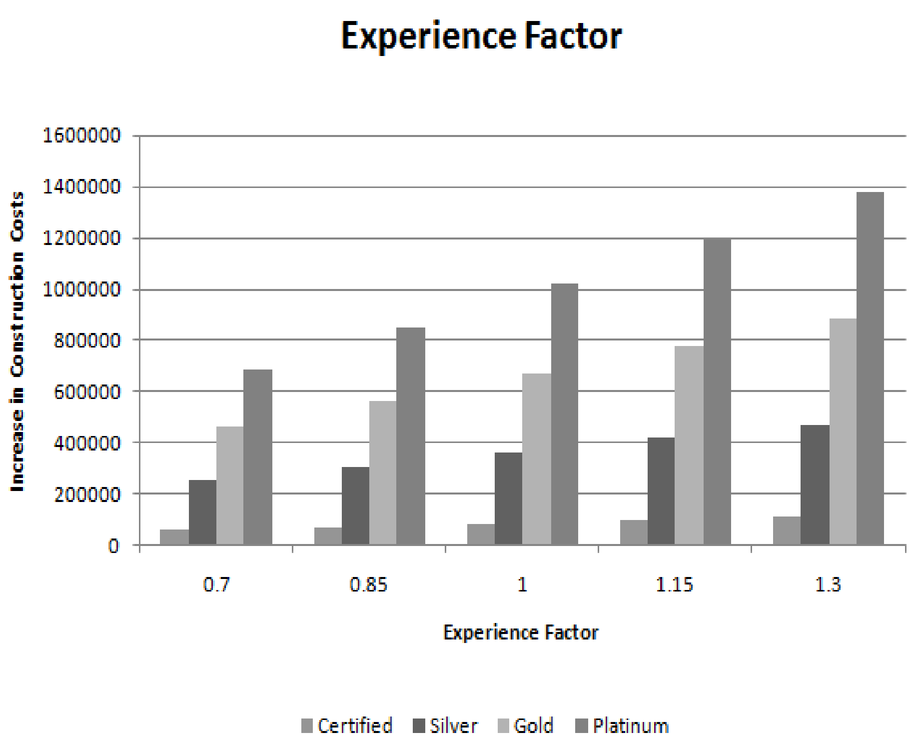

Figure 4-7. The effects of the level of experience of the contractor and the level of certification.

CHAPTER 5
SUMMARY AND CONCLUSIONS

Summary

Green building, while becoming the standard in modern construction, still has risks involved from the view of the contractor. This is evidenced by the increase in the bid price that is seen in projects that pursue a level of green certification under a building rating system such as the LEED system that has become enormously popular in the United States. The level of risk that is included in a project varies, and the behaviors that the contractor follows to deal with this risk vary also. While each project is unique, the goal of this study is to help to define some of the interactions that occur between the variables that define the included risk and the ways that this can affect a construction project. This was accomplished through the use of a model that allows the calculation of an expected bid price based on a number of variables and assumptions that take into account; standard building price, perceived risk, risk aversion policies, bidding environment, experience, and location factors. This model can be used to examine the interactions between these factors, and the resultant effects on the price of a project.

Conclusions

This study produced a number of meaningful conclusions. Through the sensitivity analysis it can be shown how the variables included in the model interact with each other. From this analysis of an example project, it was seen that the factor that had the most impact on the project price was the bidding environment. When the bid environment becomes too hostile, the bid prices that are seen tend to spike, particularly in the higher levels of certification as shown in Figure 5-1. This is due to the severe decrease in the number of bidders that are willing to bid on the project. As the number of bidders approaches zero, the cost of the project goes to infinity. As the number of bidders increases, the price comes down, but at a slower rate as the number of bidders gets larger. This creates an optimal range of the number of bidders that is project specific and should be analyzed.

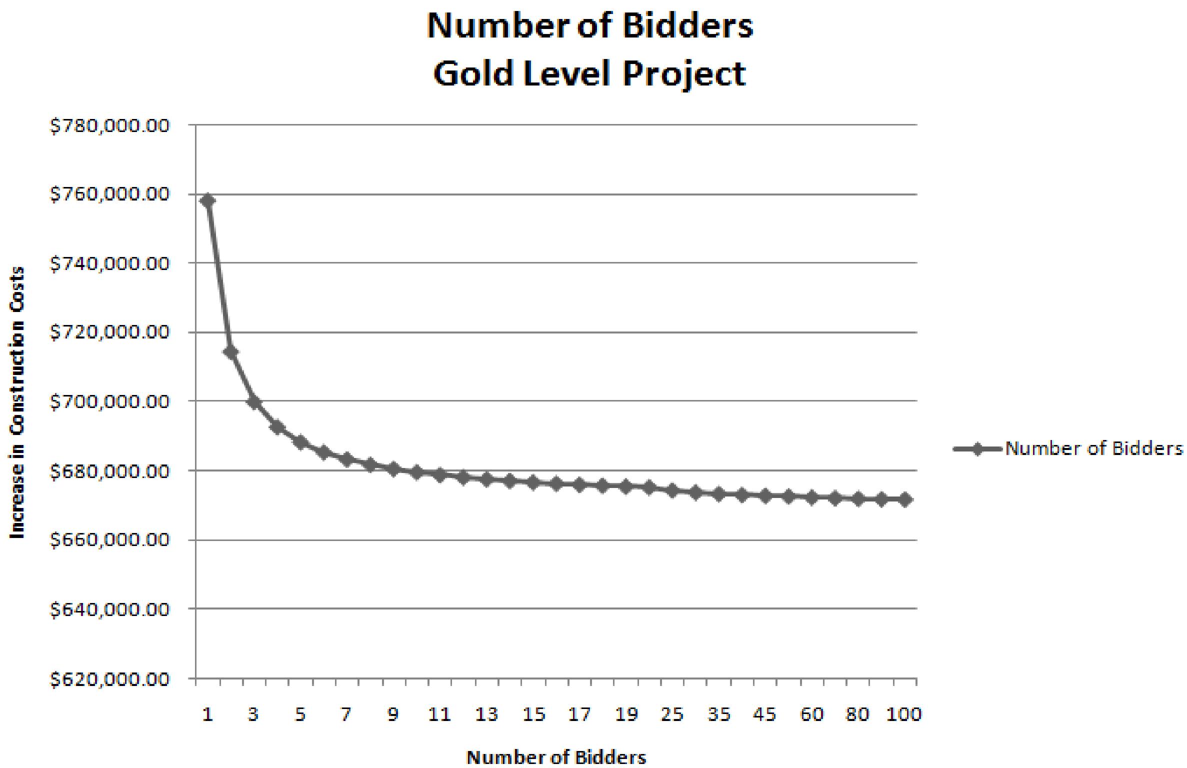

Figure 5-1. Effects of the number of bidders on a LEED Gold project.

The perceived risk that the bidder recognizes is pushed through to the owner as an increase in the cost of a project. This perceived risk is then amplified or partially negated by the risk behavior of the contractor. If high performance buildings are to become the standard buildings in the future and be priced similarly, this perceived risk must be eliminated. What remains to be seen is whether this additional price will be absorbed into the standard building price, or will be removed entirely. If it were absorbed into the standard building price, the cost of these buildings would not be reduced, but the variations in the bids would become smaller as experience increased and the extra cost would cease to be an extra risk premium and would become part of the standard building cost. The other option is that the cost currently associated with risk could disappear. If this cost is solely based on risk and has no grounding in actual costs, then the cost may vanish as the contractor pool becomes more sophisticated.

The true solution is probably somewhere in the middle. There is evidence that LEED projects do cost more, such as direct costs that are required for enhanced documentation, and extended schedules. These costs though, are relatively minimal. Most of the extra cost that is witnessed in certified projects stems from the perceived risk of the contractor, and the negative effect on the bidding environment that this risk entails. As contractors become more experienced perceived risk should be reduced. Contract language will be refined that will appropriate risk in a more standardized manner, allowing for the construction industry to become accustomed to this type of environment. This will promote a more open bidding environment that will allow for a more beneficial, competitive auction environment.

CHAPTER 6
RECOMMENDATIONS FOR FURTHER STUDY

Some interesting opportunities for future research are presented in this study. The model should be used to evaluate real world data and applied to a specific situation. A particular owner could learn how their decisions could affect expected bids, of a contractor could use this tool to become more aware of the bidding environment that they are entering into. This may make the participant more educated on the factors that affect decisions in this arena.

One area is in the effects that contract language has on the perceived risk to the bidder in a green building scenario. Some contracts have wording in them that makes certification such as LEED the responsibility of the contractor. This is questionable since most of the LEED credits are geared toward design. Examining how contractors are dealing with this could provide further insight into the decision process when submitting a bid. Examining the appropriate risk allocation in the contract documents and the effects that these have could go a long way in eliminating some of the perceived risk that results in increased costs.

Another potential area of study would be the bidding environment that exists for this type of project. This study showed that the bidding environment can have a very significant effect on the bid prices that are offered. A closer look at factors that are producing an unnecessarily hostile bid environment should be looked at, as this could increase costs sharply. An environment that is too open could also increase costs due to an overabundance of inexperienced bidders.

A closer study of the make-up of the risks perceived by contractors could also be performed. This extra cost is generally considered by the contractor, but many of them probably don't even realize it. If a contractor is adjusting a bid up 8% to account for the additional risks involved, where is this number coming from, and is the contractor aware of what is going into this cost? A good question to a pool of contractors could be to ask them to list the risks that they feel they are subject to on a certified green project and quantify the level of each. Different answers would probably be telling of the bid environment and the contractors risk aversion principles.

APPENDIX
SUPPORTING DATA

Table A-1. Supporting data for sensitivity analysis.

Certified					
		δ		Number of Bidders	
δ	% Increase	$ Increase in LEED Cost	*n*	% Increase	$ Increase in LEED Cost
1.0	1.01%	$83,558.90	1	1.02%	$84,155.28
0.5	1.01%	$83,260.72	5	1.00%	$83,095.06
0.0	1.00%	$82,962.53	10	1.00%	$82,962.53
-0.5	1.00%	$82,664.34	50	1.00%	$82,856.51
-1.0	0.99%	$82,366.15	100	1.00%	$82,843.25
Silver					
		δ		Number of Bidders	
δ	% Increase	$ Increase in LEED Cost	*n*	% Increase	$ Increase in LEED Cost
1.0	4.57%	$378,563.58	1	4.71%	$390,109.42
0.5	4.50%	$372,790.66	5	4.46%	$369,583.48
0.0	4.43%	$367,017.74	10	4.43%	$367,017.74
-0.5	4.36%	$361,244.82	50	4.41%	$364,965.15
-1.0	4.29%	$355,471.90	100	4.40%	$364,708.57
Gold					
		δ		Number of Bidders	
δ	% Increase	$ Increase in LEED Cost	*n*	% Increase	$ Increase in LEED Cost
1.0	8.68%	$718,746.39	1	9.15%	$757,874.62
0.5	8.44%	$699,182.28	5	8.31%	$688,313.32
0.0	8.20%	$679,618.16	10	8.20%	$679,618.16
-0.5	7.97%	$660,054.05	50	8.12%	$672,662.03
-1.0	7.73%	$640,489.93	100	8.11%	$671,792.52
Platinum					
		δ		Number of Bidders	
d	% Increase	$ Increase in LEED Cost	*n*	% Increase	$ Increase in LEED Cost
1.0	13.27%	$1,054,078.68	1	14.30%	$1,184,800.32
0.5	12.75%	$1,036,286.79	5	12.46%	$1,032,128.06
0.0	12.23%	$1,018,494.91	10	12.23%	$1,013,044.03
-0.5	11.71%	$970,104.96	50	12.05%	$997,776.81
-1.0	11.19%	$927,165.89	100	12.02%	$995,868.40

Table A-1 continued.

Certified

	Bid Climate Factor			Experience Factor	
	% Increase	$ Increase in LEED Cost		% Increase	$ Increase in LEED Cost
0.50	1.00%	$83,095.06	0.90	0.90%	$74,666.28
0.75	1.00%	$83,006.70	0.95	0.95%	$78,814.40
1.00	1.00%	$82,962.53	1.00	1.00%	$82,962.53
1.25	1.00%	$82,936.02	1.15	1.15%	$95,406.91
1.50	1.00%	$82,918.35	1.30	1.30%	$107,851.29

Silver

	Bid Climate Factor			Experience Factor	
	% Increase	$ Increase in LEED Cost		% Increase	$ Increase in LEED Cost
0.50	4.46%	$369,583.48	0.90	3.99%	$330,315.97
0.75	4.44%	$367,872.99	0.95	4.21%	$348,666.85
1.00	4.43%	$367,017.74	1.00	4.43%	$367,017.74
1.25	4.42%	$366,504.59	1.15	5.10%	$422,070.40
1.50	4.42%	$366,162.49	1.30	5.76%	$477,123.06

Gold

	Bid Climate Factor			Experience Factor	
	% Increase	$ Increase in LEED Cost		% Increase	$ Increase in LEED Cost
0.50	8.31%	$688,313.32	0.90	7.38%	$611,656.35
0.75	8.24%	$682,516.55	0.95	7.79%	$645,637.25
1.00	8.20%	$679,618.16	1.00	8.20%	$679,618.16
1.25	8.18%	$677,879.13	1.15	9.44%	$781,560.89
1.50	8.17%	$676,719.77	1.30	10.67%	$883,503.61

Platinum

	Bid Climate Factor			Experience Factor	
	% Increase	$ Increase in LEED Cost		% Increase	$ Increase in LEED Cost
0.50	12.46%	$1,032,128.06	0.90	11.01%	$911,739.63
0.75	12.31%	$1,019,405.38	0.95	11.62%	$962,391.83
1.00	12.23%	$1,013,044.03	1.00	12.23%	$1,013,044.03
1.25	12.18%	$1,009,227.23	1.15	14.06%	$1,165,000.64
1.50	12.15%	$1,006,682.69	1.30	15.90%	$1,316,957.24

Table A-1 continued.

Certified

		Proximity to Services	
	% Increase		$ Increase in LEED Cost
0.50	1.00%	$	82,962.53
0.75	1.00%	$	82,962.53
1.00	1.00%	$	82,962.53
1.25	1.00%	$	82,962.53
1.50	1.00%	$	82,962.53

Silver

		Proximity to Services	
	% Increase		$ Increase in LEED Cost
0.50	4.44%	$	367,622.73
0.75	4.44%	$	367,925.23
1.00	4.45%	$	368,227.72
1.25	4.45%	$	368,530.22
1.50	4.45%	$	368,832.71

Gold

		Proximity to Services	
	% Increase		$ Increase in LEED Cost
0.50	8.21%	$	680,315.92
0.75	8.22%	$	680,664.80
1.00	8.22%	$	681,013.68
1.25	8.23%	$	681,362.56
1.50	8.23%	$	681,711.44

Platinum

		Proximity to Services	
	% Increase		$ Increase in LEED Cost
0.50	12.25%	$	1,014,614.49
0.75	12.26%	$	1,015,399.72
1.00	12.27%	$	1,016,184.95
1.25	12.28%	$	1,016,970.17
1.50	12.29%	$	1,017,755.40

LIST OF REFERENCES

Alquier, A.M., and Tignol, M.H. (1999). *Project management technique to estimate and manage risk of innovative projects*, Universite Toulouse 1, Anatole, France.

Anderson, M. K., Bidgood, J.K., and Heady, E. J. (2010). “Hidden legal risks of green building.” *The Florida Bar Journal*, 84(3), 35-41.

Capen, E.C., Clapp, R.V., and Campbell, W.M. (1971). “Competitive bidding in high-risk situations.” *Journal of Petroleum Technology*, 23(6), 641-653.

Dyer, D., and Kagel, J.H. (1996). “Bidding in common value auctions: How the commercial construction industry corrects for the winner’s curse.” *Management Science*, 42(10), 1463-1475.

Esö, P., and White, L. (2003). *Precautionary bidding in auctions*, Centre for Economic Policy Research, London.

EVStudio. (2010). “Cost per square foot of college building types by region.” <http://evstudio.info/2010/05/10/cost-per-square-foot-of-college-building-types-by-region/>. (May 30, 2010).

Fu, W.K., Drew, D.S., and Lo, H.P. (2002). “The effect of experience on contractors’ competitiveness in recurrent bidding.” *Construction Management and Economics*, 20(7), 655-656.

Kibert, C.J. (2008). *Sustainable construction: Green building design and delivery*, 2nd Ed., Wiley, Hoboken, N.J.

March, J.G., and Olsen, J.P. (1976). *Ambiguity and choice in organizations*, Universitetsforlaget, Bergen, Norway.

Mathiessen, L.F., and Morris, P. (2004). *Costing green: A comprehensive cost database and budgeting methodology*, Davis Langdon, London.

Morgan, M., Granger, M.H., and Small, M. (1990). *Uncertainty: A guide to dealing with uncertainty in quantitative risk and policy analysis*, Cambridge University Press, New York.

Morris, P., and Mathiessen, L.F. (2007). *Cost of green revisited: Reexamining the feasibility and cost impact of sustainable design in the light of increased market adoption*, Davis Langdon, London.

Northbridge Environmental Consultants. (2003). *Analyzing the cost of obtaining LEED certification*, Washington, D.C.

Steven Winter Associates Inc. (2004). *GSA LEED cost study: Final report*, Norwalk, Conn.

Tang, F., Zong, W., and Song, S. (2006). *Tenders with different risk preferences in construction industry*, Department of Economics, University of Nevada, Reno, Nev.

Thaler, R.H. (1998). “Anomalies: The winner’s curse.” *Journal of Economic Perspectives*, 2(1), 191-202.

USGBC (2010). “USGBC: Intro – What LEED is.” <http://www.usgbc.org/DisplayPage.aspx?CMSPageID=1988> (May 29, 2010).

BIOGRAPHICAL SKETCH

The author was born in Connecticut and attended the University of Connecticut, receiving a Bachelor of Science degree in Finance from the School of Business Administration. After working for several years for a contractor in Hartford, Connecticut the author relocated to Florida to attend the University of Florida in pursuit of a degree of Masters of Science in Building Construction. The author plans to return to Connecticut to continue his career.