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GREEN LIQUIDATED DAMAGES: DETERMINANTS OF THE OWNER'S RECOVERY MECHANISM

by
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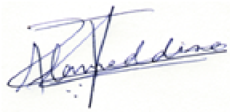

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ABSTRACT
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Literature concerned with green buildings show that they provide an array of benefits. Owners of construction projects incur an additional investment in their attempt to achieve a third-party green certification for their projects. To protect the owner's interests, appropriate contractual mechanisms must be devised to allow the recovery against potential damages upon not achieving the desired certification. As such, the objective of this research revolves around investigating a mechanism for the recovery of green liquidated damages (GLD). The steps followed in this work involved: synthesizing guidelines related to the assessment of liquidated damages, determining the components of GLD, proposing a theoretical model that can assist in deciding on the rate of recovery, and determining the credits that are statistically significant for achieving various desired certification levels. Data available on 349 Leadership in Energy and Environmental Design (LEED) projects was used to determine the significant credits and thereby validate the proposed theoretical model. The research's main findings showed that the credits governing the failure from a desired level to the following lower level are different from those governing the failure to the next or later levels. The work outcomes contribute to helping project owners identify the rates at which GLD may be levied.

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ABBREVIATIONS

LEED	Leadership in Energy and Environmental Design
GLD	Green Liquidated Damages
USGBC	United States Green Building Council
GB	Green Building
DLD	Delay Liquidated Damages
PLD	Performance Liquidated Damages
FOH	Field Overhead
AC	Accident Costs
VOT	Value of Time
RUC	Road User Cost
VOC	Vehicle Operating Costs
FAR	Floor to Area Ratio
LT	Location and Transportation
SS	Sustainable Sites
MR	Material and Resources
WE	Water Efficiency
EA	Energy and Atmosphere
IEQ	Indoor Environmental Quality
INN	Innovation
RP	Regional Priority

CHAPTER 1

INTRODUCTION

1.1 Background

A green building is one that, throughout its design, construction and operation, aims to reduce or eliminate negative impacts on the environment [1]. Literature and industry experience have shown that green building implementation materializes an array of benefits that drive the owner to pursue certification. However, it is also accompanied with barriers and risks that could lead to third-party certification failure. The latter could lead to claims raised by the owner towards the responsible party to retain his/her lost benefits. Lots of research have been performed to discuss green buildings and their motivations, the related project delivery methods, benefits, barriers, and risks [2], [3]. However, no research work has yet explored the formulation of a contractual provision that could account for the losses encountered by the owner in case of certification failure.

Buildings are an important factor in the composition of cities; the building and construction sector provides 5 to 10% of employment opportunities at the national level and contributes 5 to 15% of national GDP [4]. However, the built environment is responsible for several environmental drawbacks; it is estimated to have a 40% share of global energy use and 30% contribution to energy related green-house gas emissions [4]. Moreover, the building sector has a considerable input to construction and demolition waste (C&DW); around 170 million tons of C&DW were generated in the United States in 2003 [5], and more than 450 million tons of waste are generated every year in the European Union [6]. Therefore, the building and construction sector became an important target for sustainable intervention to limit environmental impact [5].

These facts have encouraged the emergence of green building standards, rating systems and certifications that aim at employing sustainable design to mitigate the impact of buildings on the natural environment [7].

To ensure large scale adoption, governments set regulations and incentives to require and motivate developers to follow green building standards. Sustainable design offers a wide range of benefits. A study by USGBC on LEED certified buildings found that they consume less energy and water, emit less carbon, produce less waste, save on operating costs and increase the property value. Other benefits include higher productivity and better health that result from enhanced indoor air quality, natural daylight and proper procurement of materials [7]. The collection of benefits offered upon achieving green building certification motivated developers to invest in their projects, aiming at achieving desired certification levels.

Owners employ instruments for control to guarantee the achievement of a project’s goals, such as performance and delay liquidated damages. Similarly, green building goals should adopt contractual mechanisms to enforce desired performance or guarantee compensation upon non-conformance with requirements.

1.2 Problem Statement

Thorough literature has been performed in the area of green buildings to examine its benefits and identify the risks and barriers that practitioners might face. Some articles also discussed probable claims and advised a contractual language to better clarify owner's requirements and assign responsibilities among involved parties. However, no research work has yet proposed a formulation of a green liquidated damages clause and the associated recovery mechanism that could account for the losses encountered by the owner in case of third-party certification failure. Nonetheless, what the literature has provided will pour into this objective and will assist in its realization.

This issue hinders practitioners from further involvement in green building projects and the application of 3rd-party certifications. This highlights the importance of the emergence of new contractual provisions particularly tailored to enhance such a problem.

1.3 Research Objective

The concept of Green Liquidated Damages is introduced to guarantee the owner's interests in case his desired certification is not met. The objective of this research revolves around investigating a mechanism for the recovery of green liquidated damages. This objective was achieved by proposing a theoretical model that describes the recovery mechanism of GLD, determining the components of GLD, and providing a framework that assists the owner in determining the GLD recovery rates.

1.4 Methodology

The aim behind this research is to discuss the concept of GLD recovery mechanism. To be able to perform this goal, other forms of liquidated damages were overviewed, mainly those tackling delay and performance liquidated damages. Literature review was performed to determine LD assessment methods, the parameters to be taken into consideration, and the conditions set by the standard forms of contract and governing laws. Three main factors were chosen to be explored in this literature: the components of GLD amount, the rate of levying GLD and the investment related to LEED credits.

An overview of the costs and benefits associated to LEED certification was be performed. This helps in understanding the type of extra costs that the owner incurs in order to achieve certification, and the desired benefits that he will no longer be able to retain.

Using information provided on the USGBC website, data collection was performed on 349 projects certified under LEED BD+C rating system version 4. Records regarding the number of points achieved by each credit for each project were collected. Statistical analysis was performed using regression tree and random forest functions provided by R Software. The goal was to determine the significant difference in credit achievements among projects of different certification levels. This provided an overview of the credits that must be achieved to secure a high certification level. The statistical analysis results were used to verify a proposed theoretical model for rate of levying GLD. Statistical analysis was also associated to relate cost components of LEED credits into the GLD amount.

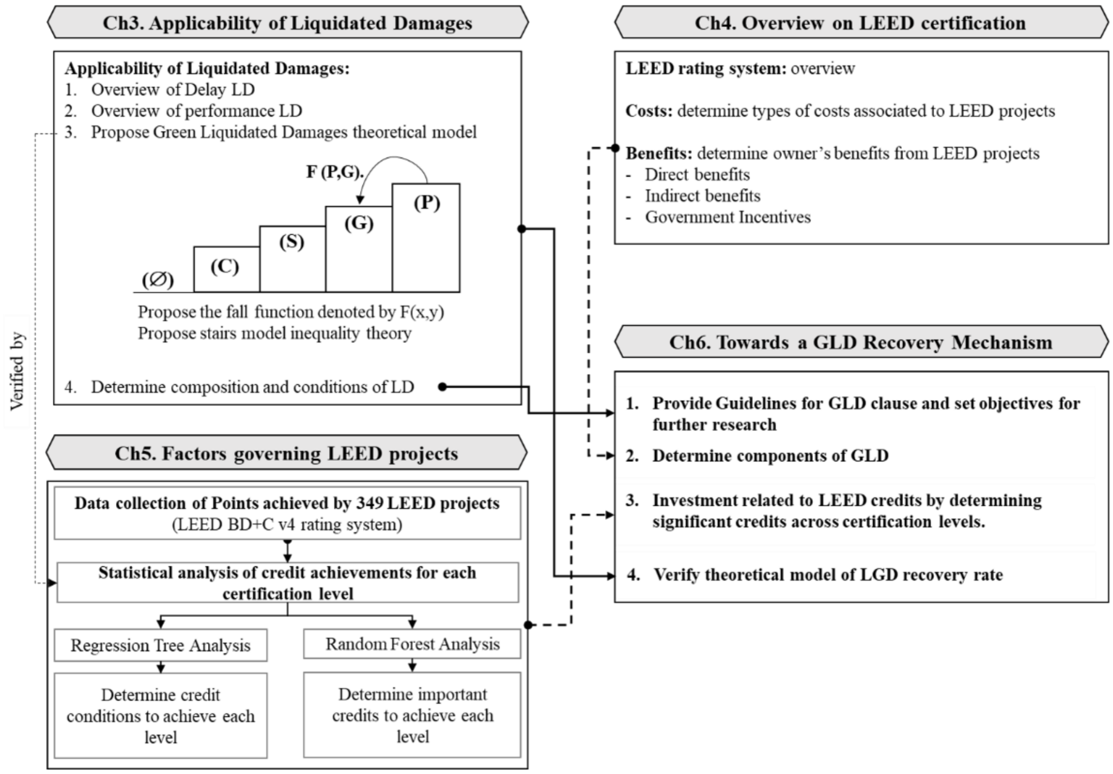


Figure 1 Research Methodology

1.5 Thesis Organization

This thesis is divided into seven chapters.

- Chapter 2 provides an overview on the literature around green buildings and a brief definition of green buildings. Then an overview on owner's instruments for control on project goals was performed. Green building's possible claims and a collection of case law related to green buildings were viewed.

- Chapter 3 presents an overview on delay liquidated damages and performance liquidated damages and introduces the concept of green liquidated damages and the proposed theoretical model. Then liquidated damages assessment methods and conditions from the literature are explored.
- Chapter 4 provides an overview on LEED certification, and presents information regarding LEED certification premium and benefits as discussed in the literature.
- Chapter 5 presents the data collected on LEED certified projects and the statistical analysis performed on it. Additionally, this chapter reflects the results that represent factors governing LEED certified projects.
- Chapter 6 aims to approach GLD recovery framework. The first part determines the components of GLD in reference to the findings of chapter 4, whereas the second part explains the rate for levying GLD and verifies it using statistical analysis results. Finally, the results are combined into a framework that describes the ceiling, recovery values to be stated in the contract, and relates statistical analysis results into these values.
- Chapter 7 summarizes the research contributions, results, limitations and recommendations for future research.

CHAPTER 2

LITERATURE REVIEW

2.1 Preamble

This chapter provides a brief introduction on green buildings (GB) and their literature. The literature includes reasons for GB adoption, and the associated barriers, risks and claims. In addition, a collection of case law resulting from GB issues is presented. Furthermore, an overview for owner’s instruments for control over projects will be provided.

2.2 Introduction to Green buildings

Due to the negative environmental effects imposed by the construction industry in the past decades [4], the concept of green buildings started to emerge in the aim of controlling the environmental effect of the construction industry. Green buildings are designed in a way that minimizes or completely removes negative impacts on the environment throughout its construction and operation [1]. With time, green building standards and rating systems started to form throughout the world in the aim of standardizing green building practices and fostering them.

The Building Research Establishment's Environmental Assessment Method (BREEAM) launched in 1990 was the first green building rating system in the world [7].

It was then followed by the formation of the United States Green Building Council (USGBC) in 1993, which launched its first Leadership in Energy and Efficiency in Design (LEED) green building rating system in 2000 [8]. Other standards and certifications were established all over the world as well; such as Green Star developed in Australia and the Hong Kong Building Environmental Assessment Method (HK-BEAM) [9]. Later on, lots of building standards emerged; such as CASBEE (Comprehensive Assessment System for Built Environment Efficiency) that is an industry standard used in Japan and [10], and WELL building management program that is managed by the international WELL building institute launched in 2014 [11]. Later, almost every country established a rating system suited to its environment and resources.

All the aforementioned standards aim to achieve a group of features to ensure that the project certifies enhanced performance across key environmental attributes. These features comply with and aim to fulfill the three pillars of sustainability: the environment, the economy and the society [12]. An article by the World Green Building Council determines these features as the following [13]:

- To use energy, water and other critical resources efficiently
- To employ renewable energy resources, such as solar or wind energy
- To follow pollution and waste reduction measures in addition to enhancing reuse and recycling activities
- To achieve good indoor environmental air quality

- To use non-toxic, ethical and sustainable materials
- To take consideration for the environment and quality of life for occupants throughout design construction and operation phases of the project
- To have the design capable of adapting to changing features of the environment

2.3 Overview on Green Building literature

Topics on Green Buildings are rising these days. A review of over two decades of published research covering 130 articles related to green buildings shows that 52% and 83% of articles in the sample have been published during the last five years (2014-18) and ten years (2009-2018) respectively [2]. The literature is mainly classified into areas dealing with motivations, project delivery, benefits, barriers and risks [2], [3].

2.3.1 Reasons for green building certification

Several research papers on green buildings have explored reasons for certification by the owner. They can be generally categorized as direct and indirect benefits. Some seek certification because of its operational advantages such as energy and water savings, and operation and maintenance costs [14], [15]. Other owners are interested in the financial benefits such as beneficiary financing, tax incentives and building incentives [15]–[20]. Moreover, aiming for certification could simply be mandatory for applying to a public project or having it as a state law [16], [17], [19].

These factors could be quantified with a monetary value, thus losing them could be considered as a direct damage. It also has advantages for occupants such as increased comfort, enhanced productivity, lower health costs, and improved air quality [14], [15], [18], [20], [21]. Certification could also be an assurance of corporate's commitment to sustainability, or to gain marketing benefits [16] [17]. These benefits do not have a clear monetary value, thus losing them could be considered as a consequential damage.

The aforementioned reasons drive owners to pay a premium to achieve a third-party certification that could cause a significant increase in project's cost [22]. Therefore, owners must take precautions that protect them in case of certification failure, since green buildings are associated with risks and issues that could drive its achievement to become problematic.

2.3.2 Barriers to green building adoption

Several research documents have discussed barriers to green building adoption. Hwang and Leong (2013) studied factors for delay with respect to each project entity in a green building project. The top five factors for delay in green buildings turned out to be the speed of decision making by the client, the speed of decision making by project teams, coordination and communication by project key parties, the consultant's level of experience, and financing difficulties by contractors [23]. Hwang and Tan (2012) studied obstacles and stated solutions for green building adoption that relate to extra costs, complex processes, and harder communication [23]. The same authors later published an article that stated common obstacles related to the management of green building projects and offered solutions to these obstacles [24]. Afterwards, Chan et al (2017) discussed the criticality of various barriers, where their review of the literature showed that barriers can be clustered into five main categories; resistance of stakeholders to change and higher cost were identified as the most critical barriers [25].

2.3.3 Green building risks

With respect to the literature discussing risks, the reviewed papers were categorized into three main areas: some discussed risk factors experienced in a certain country [20], [26]–[29], some studied risks perceived by each project entity [18], [30], while others reviewed the literature discussing risks and summarized them. From the third category, we mention Zhao et al (2016) who developed a framework that categorized and ranked the criticality of 28 risk factors [31]. Whereas Durmus-Pedini and Ashuri (2010) performed a review on risk factors in green buildings and summarized them into financial, marketing, industry, performance and legislative risks [15]. Moreover, Polat et al (2017) listed 25 risk factors that may affect cost and time performances of green projects. The most frequent and severe risk factors were found out to be contractor-related factors [32].

Abdul-Malak and Khalife (2020) examined how sustainable building certification risks are addressed through contract terms and investigated remedy approaches followed by professionals. Preferred approaches were ranked as follows: retain control by owner, cure by responsible participant, waive damages, and levy liquidated damages. Moreover, advices sought from practitioners related to project and contract management practices were grouped into the following categories: planning and organizing, team building, contract terms/documents, project brief, budgeting, and control [33].

Risks associated with green buildings result in the failure to live up to the owner's expectations, which leads to lawsuits[16]. The risk of third-party certification failure could drive the owner to escalate the problem and raise a claim against the responsible entity to remediate the loss. However, it is not easy to realize the claimed benefits; the owner must prove that there is a profit loss for the property, that his/her business is affected, or that this certification was mandatory [17].

Therefore, summaries of risks from the literature were associated by some to occurrence of claim. Nevius (2009) considered that the package of contracts that is entered into for the project represents an opportunity to share the risk of LEED-certification failure with all participants, so he listed going green risk issues to identify types of insurance claims [19]. Whereas Tackey-Otoo (2014) tackled this area in his Master's thesis to analyze the difference in claims between traditional and green buildings. The author concluded that green construction claims are more complicated. The reasons go back to the use of different materials and technologies, lack of experienced personnel, and difficult and expensive certification processes [34]. Moreover, Mohammadi and Birgonul (2016) identified and assessed the criticality of risk factors that may lead to claims in sustainable construction. The most important group of risk was 'third party certification risks', where its contributing factors included failure in achieving third party certifications, lost incentives due to certification failure, and decertification [35].

Tollin (2011) discussed risks pertaining to each party for potential claims. Risks for design professionals included design defects that prevent the achievement of the desired certification and the associated liabilities. Risks for contractors included general breach of construction contract resulting from not achieving desired certification, whereas owner's risks included loss of certification and the resulting loss of its benefits [18].

In light of that, Koeller Nebeker Carlson and Haluck Legal company released an article related to legal risks in green buildings. The authors attempted to understand the risks by viewing case law related to delays and its contractual issues, financing of green projects, construction defects insurance claims, green washing, and intellectual property [30].

Researchers also studied what should be written in green building contracts. Gibbons (2009) discussed what should be included in the contract concerning delays, scope, documentation, and analysis [36]. Perking (2009), on the other hand, discussed in her report the aspects that standard forms of contracts fail at and the points that a contract must address regarding representations, guarantees, specifications' documentation, and consequential damages [37]. A report by Brooklyn Legal Services further elaborated by mentioning particularities to be taken into account in the contract such as means for dispute resolution and assigning particular responsibilities of involved parties [38].

Below is a table summarizing all types of risks tackled by the reviewed literature.

Table 1 Green building risks as discussed in the literature

Type	Element	Description	References
Financial risks	**Loss of financial benefits**	Lost financial and tax incentives, financial gain against expectations, penalty for not achieving required certification	Nevius (2009) Tackey Otoo (2014) Durmus-Pedini & Ashuri, 2010) Zhao et al (2016) Hwang et al (2017) El-Sayegh et al (2018) Tao & Xiang-Yuan (2018) Hwanga et al (2017) Qin et al (2016)
	Financing problems	Shortage of funds, overlooked high initial cost, additional costs due to green construction and certification process	
	Macroeconomic risk	Increasing inflation rate, inflation of green material costs, considering lifecycle inflation impact, currency exchange rate fluctuation, currency volatility worsened by green material import, limited surety bonds, low payback rate	
	Cost overrun risk	Inaccurate investment estimation, Inaccurate estimation of return on investment, increased cost of conducting a green building standard assessment, inaccurate quotation of contractors	
	Locality	Change of government support policy, Green building market demand forecast is not allowed	
construction risks	**Material and technology**	Delay, quality, durability and availability problems, poor performance, long lead time, default supply, poor selection of construction techniques, limited availability of reliable suppliers, lack of clear definition of green materials.	Tackey Otoo (2014) Kim (2018) Zhao et al (2016) Hwang et al (2017) El-Sayegh et al (2018) Tao & Xiang-Yuan (2018) Hwanga et al (2018) Qin et al (2016) Polata et al (2017)
	Delay in schedule risks	Inaccurate estimations, delay due to frequent green meetings, tight schedule	
	Team related	Labor: lack of expertise, poor training, workmanship, and productivity Subcontractors: unfavorable, limited availability of reliable ones Management: lack of experience and knowledge, inefficient communication, coordination and organization, irrational assignment of responsibilities	
	Client related	Goal uncertainty, poor scope definition, unclear requirements, design changes, intervention, delayed payments, resistance to adopt new ideas	
	Design problems	Unclear detailed design or specs, insufficient design information, inexperienced designers, limited creativity and innovation, slow response to change orders, negligence of constructability in designs	
	Contractor related	Unfamiliarity with new technologies, construction methods, products, specifications and waste management system	
	Safety and restrictions	Strict safety and health regulations, employment constraints, pollution restrictions, import/export restrictions	
	Procedure complexity	Complex planning approval and permit procedures, delay in issuance of documents, long approval process of material and techniques	
	Technical problems	Technical complexity, use of new construction method and technology, lack of documents and information for new green technology	

Table 2 (Cont'd) Green building risks as discussed in the literature

Type	Element	Description	References
Market and industry risks	**Market risks**	Misconception about efficiency, challenges for homeowners, setting expectations too high, poor public acceptance, intellectual property concerns	Durmus-Pedini & Ashuri, 2010) Nebeker et al Hwang et al (2017) Qin et al (2016)
	Qualifications	Lack of qualified professionals with proper design, misrepresentation of expertise and competence	
	Supply-related factors	Limited number of green building material suppliers, need for imports, long lead time, long quotation time, new suppliers.	
	Demand	Inaccurate prediction of market demand, huge demand leads to inflation, not engaging GB practices, increased demand vs supply, attitude to financial market is underestimated	
Legislative	**Claims**	Breach of warranty, breach of contract, construction products liability, fraud allegations, negligence, premises and strict liability claims upon not giving adequate warning for property condition and inspections, express warranty claims, professional regulation damages, claims of overstated or unverifiable benefits	Durmus-Pedini & Ashuri, 2010) Nebeker et al Hwang et al (2017) Qin et al (2016) Mohammadi & Birgonul (2016) Tackey Otoo (2014) Kim (2018) Zhao et al (2016) El-Sayegh et al (2018)
	Standard of care	Elevated Standard of care and professional liability coverage for ENG, Architect, contractors, Material vendors, construction managers, GB consultants	
	Contracts	Standard forms inefficiently address GB requirements, failure of proper risk allocation, inadequate definition of contractual roles and responsibilities, unclear contract conditions for dispute resolution, claims and litigation, responsibility on credit achievement	
	Regulations	Change in incentives, inconsistencies between formal regulations and LEED, delay and complicated approval procedures, changes in sustainable construction codes and regulation, incomplete regulations for GB.	
Performance risks	**Faulty/ uncertain performance of building components**	HVAC systems to achieve dehumidification, electrical, plumbing, water, power systems	Tackey Otoo (2014) Durmus-Pedini & Ashuri, 2010) Kim (2018) Hwang et al (2017) El-Sayegh et al (2018) Tao & Xiang-Yuan (2018) Mohammadi & Birgonul (2016) Nevius (2009)
	High performance standard	Operational performance fails to meet project objectives, evaluation results did not reach the expected level	
	Negative impact on Society	Poor construction environment and habitability, construction accident, low public satisfaction	
	Certification	Failure in achieving 3rd party certification, decertification, lost incentives due to certification failure, stringent third party certification standards, high target for certification level	
Insurance	**Scarcity of insurance alternatives**	Energy savings insurance, upgrading after damage, indoor environment, reputation damage, director and officer protection	Nevius (2009) Tackey Otoo (2014) Kim (2018) Qin et al (2016)

2.3.4 Green Building Claims

Green building projects provide plentiful opportunities for liability and litigation. Claims eventually arise when the end-user fails to receive the desired expectations. According to the literature, claims possible to arise are the following:

2.3.4.1 Misrepresentation

Green buildings provide a competitive edge for developers to attract customers at heightened prices. On the other hand, customers pay the premium only because they expect a better product. Therefore, the developer's failure to satisfy the buyer's expectations would lead to claims under misrepresentation, since the product was misrepresented. Prum and Percio (2009) discussed the three types of claims that could occur. The first is claim of "Deceit", which applies when the defendant intends to *knowingly mislead* the plaintiff. The second is claim of "Negligence", where a breach of duty towards the plaintiff must occur and this breach causes damage. In this case, failure to adhere to green building standards is a breach of the duty to deliver a green building, where duty is determined by the prevailing industry's standard of care. The third is "Strict liability". In this case, liability is imposed when the defendant doesn't intentionally intend to cause harm; courts automatically consider contractors liable when negligent work is performed [39].

2.3.4.2 Warranty theory

The warranty theory allows for claims under the economic loss. Where the plaintiff must first prove that the defendant did make a warranty in either of its forms: implied or express warranty. The plaintiff must then show that goods lacked compliance with this warranty. Finally, the plaintiff must establish that injury happened due to defective damage of goods, since both proximity and cause are needed for the success of the claim. To defend this claim, the defendant might resort to the use of disclaimers, absence of privity, lack of notice, or that the claim is outside the statute of limitations [39].

Claims under warranty theory could be either expressed warranty or implied warranty. The former occurs when the warranty or guarantee for the product or service is given from the supplier either in a spoken or written form [40]. Whereas claims under the latter must be implied by the basic function of the product or service itself [41]. To avoid tenant claims, the owner may want to add language into his lease agreement that expressly disclaims any express or implied warranty against the expected performance benefits such as having increased productivity for employers or reduced sick days [36].

2.3.4.3 Breach of contract

This case occurs when a party fails to perform according to its promise. Usually, the prevailing party receives damages to cover the necessary costs for reconstruction to bring it back to the promised level. It has two types [39]:

1. Claim for material breach:
   - Happens prior to the completion of the contract
   - Material breach causes real harm to the contract such that impairs its value [42]

2. Claim for substantial performance breach:
   - Occurs after some type of performance
   - Performance must not vary greatly from what was originally promised; only slight difference from the contract agreement, and should provide similar results [43].

2.3.4.4 Patent infringement

This case has a higher likelihood of occurrence when innovation is incorporated into the green building project. In general, the owner must include an intellectual property (IP) indemnification clause into any Owner-Architect agreement against copyright or patent violations for products or systems stated by the architect in the drawings, specifications or other documents. While the architect must first make sure that all products and systems included are properly investigated against this risk, and make sure to have sufficient insurance coverage against IP claims [36].

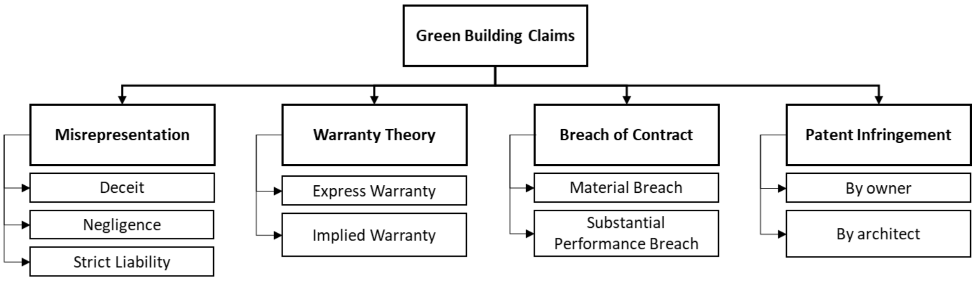


Figure 2 Summary of the Claims that Might be Encountered with Green Building Projects

2.4 Green Building Case Law

Due to their several unique features, green buildings are prone to additional liability than those in standard claims [30]. Mostly, these claims arise from a disappointed end user whose delivered project did not comply with his high expectations[44]. Therefore, it is important to draft a contract that clearly translates the owner's green requirements and to follow a plan that ensures all tasks are performed at the right time. This section examines legal cases that are a result of green building claims. Table 2 shows a combination of claims according to the parties involved and the issue from which the claim aroused.

Table 3 Summary of Green Building Case Law

	Tax/incentives issue	Not certified as agreed	Documentation (procedural)
Developer v. contractor	Southern Builders v. Shaw Development		
Government v. developer	Internal Revenue Service (IRS) v. large-scale mall project		
Purchaser v. developer		Keefe v. Base Village Owner, Barber v West Chelsea Development Partners	
Homeowner v. architect		Bain v. Vertex Architects	
City v. contractor			City of Palo Alto v. Flincto Pacific
Owner v. developer and arch.		Steven Gidumal v. Site 16/17 Development	

a. Shaw Development v. Southern Builders, LLC

The case of Southern Builders v. Shaw Development (Feb. 7, 2007) is the first case of green building litigation involving private parties[30]. The project related to this lawsuit is a USD7.5 million development in Crisfield, Maryland called Captain's Galley. Claims started when the project's general contractor, Southern Builders, filed a mechanics lien against the owner, Shaw Development, due to construction delays. However, the owner counterclaimed against the general contractor for lost tax credits because they did not achieve the certification in a timely manner[44]. The main issue is that the case relates to a generic contract containing standard provisions with the only green related provision stating that the building should comply with LEED silver requirements, but without stating which party is responsible for certification [30].

b. City of Palo Alto v. Flintco Pacific, Inc.

The project related to this lawsuit is Mitchell Park library, a proposed LEED Platinum project. When the project was 90% through completion, Flincto Pacific, the general contractor, was fired and a new contractor was chosen to take over construction. Later on, the City claimed that Flincto Pacific did not turn over the documentation necessary to pursue LEED documentation when the contract was terminated[45]. Their claim stated that the missing documents relate to the "source and specific type of materials incorporated into the project, methodologies employed by the contractor to reduce waste and impact, and a significant number of other requirements." [46]. Flincto Pacific replied that it had submitted to the City all of the documents available in its construction trailer, whereby these documents are responsive to all deliverables stated in the construction contract [45].

c. Steven Gidumal v. Site 16/17 Development, LLC

One of the remarkable cases to date for green construction defect litigation was that of Steven Gidumal. v. Site 16/17 Development LLC (May 6, 2010). This suit was filed by the owner of a USD4.2 million condominium unit in the River house apartment in New York City against the building's developer and manager for damages in the building related to green construction defects [47]. Steven Gidumal, the plaintiff, filed a complaint against the architect for breach of contract, fraud, negligence and negligent misrepresentation. One of the complaints asserted the failure of the "green" HVAC unit in delivering heat. In addition, experts assigned by the plaintiff found remarkable deviations from the requirements of the LEED Gold building, which lead to claims against the architect for malpractice and fraud and the owner for construction defects[30].

d. Internal Revenue Service (IRS) Vs. large-scale mall project

The American Jobs Creation Act of 2004 authorized states or local governments to issue private activity "green bonds" as tax exemptions reaching up to USD2 billion for qualified green building and sustainable design projects. In 2007, the developer of a large-scale mall project received USD228 million from the federal green bonds program for installing renewable energy and green building technologies into his project. Three years later, the developer declared that the project may fall short on achieving many of the renewable energy and green building features expected of the project, which might jeopardize the achievement of LEED Certification. Consequently, the IRS opened an audit to check if they shall revoke the USD2 million exempted taxes. Three years later, the IRS accepted the developer's argument that the unfulfilled features do not affect the promised certification, and closed the audit without impacting the tax exemption status [48].

e. Keefe v. Base Village Owner

This case included a dispute between purchasers and a project developer. The developer presented the project as a LEED certified building belonging to a LEED certified neighborhood. Later on, the purchasers sought to rescind their purchased contracts since both the building and the neighborhood did not turn out to be LEED certified [48].

f. Bain v. Vertex Architects

The homeowner of a farmhouse filed a suit against the architect for not pursuing and obtaining LEED certification from the USGBC for his farmhouse renovation project. The plaintiff, i.e. the homeowner, alleged that the architect contractually agreed to "create a sustainable green modern single-family home" [48].

g. Barber v West Chelsea Development Partners

The purchasers filed a suit against developers claiming breach of contract and fraud since the latter failed to achieve LEED certification and to comply with state energy code. The plaintiffs sued to get their sales contracts rescinded and to get a refund on their earnest money deposits (EMD) [49].

2.5 Owner control tools over project

Owners practice several instruments to maintain control over project goals and to ensure that the contractor performs his obligations as agreed upon. These instruments aim to ensure contractor's compliance with time, quality and fulfillment of obligations with all involved parties. Owners usually employ a group of instruments to maintain the aforementioned desired goals:

1. Performance guarantee: this method requires the contractor to submit a document that legally confirms that the he/she will complete the contract as agreed. It is submitted by an insurance company or a bank on behalf of the contractor. It provides credibility and ensures the owner that the work would be performed properly. In case the contractor does not perform in compliance to the specifications set by the contract, the amount specified by the performance bond is sufficient to compensate for any consequent monetary losses [50].

2. Retention bonds: this tool is available to secure both the owner and the contractor's interests. Retention, as a concept, is present to ensure the proper completion of works by the contractor, where a specific percentage of contract value, usually between 2.5% and 5% is retained until the passage of the defects liability period [51]. The defects liability period is a predetermined duration, following the completion of works, set to track the project defects to be

remedied by the contractor. Therefore, this bond insures the owner that coverage is available for the contractor to fulfill his works properly, and at the same time insures the contractor that he will receive all agreed payment certificates without having retention monies being held [51].

3. Advanced payment guarantee: in some projects, owners provide contractors advanced payments at the beginning of the project to enhance the construction workflow, to aid the contractor in case significant startup costs are present, or to facilitate procurements performed by the contractor [52]. To ensure that the contractor uses the money in their intended aim and to guarantee the owner's interests, advanced payment guarantee or bond is required from the contractor to secure the payment against default [52].

4. Parent company guarantee: in certain cases, parent companies provide guaranties to their subsidiary companies to support their financial credibility when they enter into a commercial contract with third parties [53]. This guarantee provides extra comfort to the third party that ensures that the subsidiary company will perform according to their obligations to the contract. The central provision on which this guarantee is based upon provides the employer the ability to recover from the guarantor the losses incurred due to the contractor's breach or insolvency [53].

Owners can practice some or all of these instruments to ensure that the desired performance is guaranteed. For example, in the case of recovery of delay liquidated damages, owners can use performance security for an amount equal to the delay damages reduced by collected progressive payments, such that the total collected money by the owner is equal to the full amount of delay damages [54]. Moreover, the owner can retain money from agreed progress payments, or use retention bonds to release the unpaid progress payments, to prevent hindering contractor's ability to finance the project, while maintaining owner's guarantee.

For the context of this research, the owner can use the various instruments available by the contract to compensate for the damages that might be incurred instead of third-party certification failure. The following chapter discusses the applicability of liquidated damages by discussing delay and performance liquidated damages and introducing the concept of Green Liquidated damages.

CHAPTER 3

APPLICABILITY OF LIQUIDATED DAMAGES

3.1 Preamble

Owners aim to practice instruments for control to achieve project objectives. Of these instruments are delay liquidated damages (DLD), which can be set to have control over project's completion date, and performance liquidated damages (PLD), which target project's desired performance. This research work aims to introduce a new concept for liquidated damages that targets green building certification achievement. Green Liquidated Damages (GLD) are conditional on the achievement of the owner's desired certification. In order to adopt a reliable assessment of GLDs, other types of construction damages have been explored. The following chapter first introduces delay liquidated damages and performance liquidated damages concepts. Then, the concept of Green Liquidated Damages is proposed along to a theoretical model for assessment of losing a desired certification and ending up at another. Moreover, in order to have an enforceable liquidated damages provision, assessment of liquidated damages in the literature is performed, and conditions concerning the enforcement of LDs are studied by reviewing the conditions set by jurisdictions and standard forms of contract.

3.2 Delay liquidated damages

One of the main project objectives that the owner holds tight to maintain is the contractual completion date, since it is directly related to the costs and revenues associated to the project. Previously, project owners used to seek litigation to compensate for the damages that result from delays in project completion [55]. However, the assessment and calculation of the damages incurred due to delay may be very difficult to determine when the delay actually takes place, therefore it is more preferable to have a predetermined agreement on this amount [56]. Consequently, owners started introducing a liquidated damages (LD) clause into their construction contracts. LDs represent a previously agreed sum, that the owner and contractor agree upon, entitling the owner to compensate for the delay incurred beyond a specified contract completion date [57]. To quantify the LD amount, a daily dollar assessment for every day of delay incurred due to the contractor is determined.

Liquidated damages have basic principles to become enforceable by law. In “Enforcement of Liquidated Damages”, Thomas et al discussed six basic principles of enforceability of liquidated damages [55]:

1. Contractor’s delays must be non-excusable: the contractor is responsible for determining the construction schedule based on his knowledge of the works and the employees’ productivity, and he must perform proper coordination with subcontractors. Therefore, any miscalculation of works or improper coordination that cause a delay of works is considered non-excusable delay. Consequently, the owner must be compensated for it.

2. Apportionment of damages: in certain cases, both the owner and the contractor are responsible for the delay. These types of delays are known as concurrent delays, and in these cases the contractor becomes responsible to compensate solely for the damages that he is accountable for.

3. Liquidated damage amount: the amount of liquidated damages evaluated by the owner must reflect actual damages incurred in case of delay. Owners usually estimate it based on the lost revenue, rental values, overhead costs, engineering and administrative costs, extended management and wages, and interest values. Determining an LD amount is critical since a high amount may deter contractors from bidding into the project.

4. Period of assessment: the contract language must be very clear in determining the date from which the owner can start levying LDs; whether substantial completion or final completion. Moreover, the calendar must be determined as whether calendar days or working days.

5. No concurrency with actual damages: delay liquidated damages are set to compensate for the damages incurred by the owner due to delay; therefore, the owner cannot claim for damages and levy LDs at the same time.

6. Not a penalty: the determined amount must be a genuine estimate of the incurred losses; therefore, a compensation rather than penalty for delay. Excessively large amounts proved as penalty are not enforceable by courts when contractors seek litigation.

3.3 Performance liquidated damages

Performance liquidated damages are incorporated into projects in the aim of controlling project's underperformance [58]. Similar to delay liquidated damages, performance guarantees must be determined at the time the parties enter to the contract and should reflect a genuine estimate of probable loss. This value is usually calculated by the Net Present Value (NPV) of the revenue foregone due to underperformance over the design life of the project [58].

Performance liquidated damages are mostly incorporated into EPC contracts, where performance, represented by output, reliability and efficiency, is a key factor for achieving the desired revenues from the project [59]. In contract formation, performance liquidated damages are incorporated to a group of basic features that include a cap of contractor's liability towards the project represented as a percentage of contract price. In addition, contractors must submit performance guarantees represented as a bank guarantee amounting a percentage of contract price, retentions for payments, advanced payment guarantee, and a parent company guarantee that fulfill the contractor's obligations in case the latter fails to do so [59].

It is important to carefully determine the scope of performance liquidated damages and to specify the different parts if present (which stands for efficiency, which stands for output, etc.). This plays an important role against arguments from the contractor that might try to prove the stipulated amount as being a penalty rather than compensation [58].

3.4 Green Liquidated Damages

The Green Building concept has been initiated by the intentions of having a cleaner environment and a more sustainable future. Nonetheless, the market of green buildings has attracted more than just those aiming for a better environment and has grew to include those seeking all types of benefits that could be achieved by such a certification. The fact that an owner is willing to pay a price premium to achieve a certain goal, turns the failure of this goal into a damage to be compensated by the party responsible for it. The aim of this study is to assess the damage incurred by the owner due to certification failure and incorporate a Green Liquidated Damage clause into the contract to be able to compensate for this damage.

In the case of delay LD, the rate of levying damages is determined per day and aggregated with passage of days until the ceiling of damages for that project is reached. A similar concept is followed by performance LD, where the rate is dependent on performance units. The theoretical model proposes a different approach for the rate of levying GLD. Each loss in certification has a unique value; a larger loss yields an increase in the levied amount but not an addition to previous losses.

The following chapter elaborates the proposed theoretical model that aims to illustrate the rate of recovery of GLD amount by displaying certification levels in the form of stairs. The highest certification level, Platinum, is placed at the highest step, the Gold Certification Level is placed at the step just lower, Silver certification is one step lower than gold, Certified is the lowest step and no certification is at the bottom of the stairs.

3.4.1 The fall function

Project stakeholders targeting LEED certification plan the work in a manner that satisfies their desired goal. However, if works go against plan, they might not be able to achieve their desired certification and land at a level just below the anticipated one, or they might not be able to achieve that too and end up at a lower level. That said, one could face a full fall; losing the certification altogether, a large fall; losing more than one certification level, or a partial fall; falling from a certain certification level to the level beneath it. Falls are represented by the function F (x, y), where the following applies:

- x is level that the fall starts from
- y is the level that the fall ends at

For example, F (P, G) indicates the fall from certification level Platinum (P) to certification level Gold (G). The following diagram illustrates the stairs model, and annotates the partial falls, large falls and full falls:

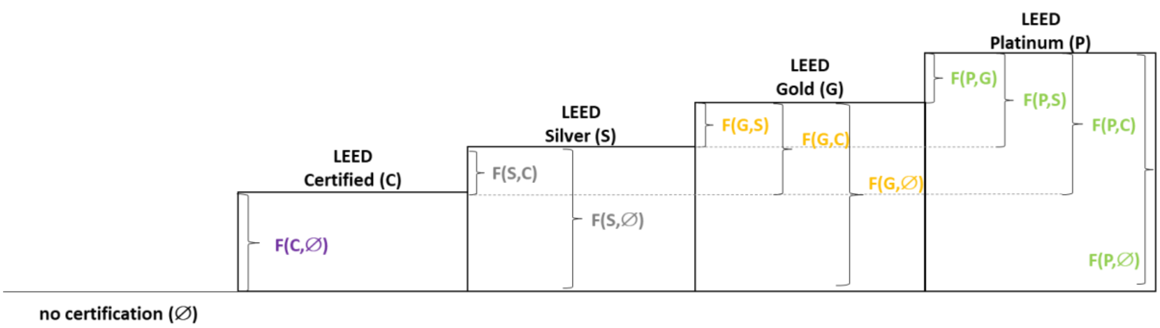


Figure 3 Theoretical Green Liquidated Damages Model

3.4.2 GLD rates: theoretical model inequality theory

A full fall denotes losing certification altogether: falling from the target certification level to no certification at all. For a full fall to happen, a project owner would lose all his chances to achieve various certification levels. A project owner aiming to get a targeted certification level will hold tight to any certification level just beneath it before ending up at the final level which could be no certification at all.

For example, a project owner aiming for Platinum certification, would hold tight on the Gold certification level in case Platinum certification was lost, and would make the responsible entity pay a liquidated damage amount to account for the loss incurred due to achieving Gold instead of Platinum. If the project could not achieve Gold as well, the owner would hope to have Silver certification, and would make the responsible entity pay a new value of loss.

In this regard, the stairs model theorizes that full falls and large falls are not equal to the summation of their partial falls. Hence, the following inequalities are proposed:

- $F(P,\varnothing) \neq F(P,G) + F(G,S) + F(S,C) + F(C,\varnothing)$
- $F(P, C) \neq F(P, G) + F(G, S) + F(S, C)$

The same applies to other large and full falls starting from Gold and Silver certifications. Chapter 6 verifies this model by employing statistical analysis results based on data of LEED certified projects.

3.5 Liquidated damages assessment

The amount assigned for damages must be carefully estimated to ensure that the amount is a genuine estimate of potential loss and cannot be considered a penalty. Due to its significance, thorough literature has been performed to provide guidelines for estimation and to provide reference for parameters and factors to be considered. The subsections below provide an overview for LD assessment methods in the literature that tackle the composition and conditions related to liquidated damages quantification.

3.5.1 Liquidated Damages Composition

3.5.1.1 Liquidated Damages assessment in the literature

The topic of delay liquidated damages is thoroughly explored in the literature since it could be faced by all types of construction projects. In “Make Liquidated Damages Work”, McCormick (2003) focused on the employment of liquidated damages in the construction contract and presented six owner guidelines to form and calculate liquidated damages. They include the following items as factors to be considered: (1) additional costs incurred by the owner in case of delay in contract, (2) lost revenue and profit per day, (3) the ongoing project administration costs to be paid throughout the delayed days, (4) the extra permitting costs in case the project is not finished on time, (5) interest costs on loans used to finance the project, (6) and finally the third party contracts that are going to be impacted by the delay of contract [56].

Crowley et al (2008) published a review for the current state of practice of liquidated damages by surveying state highway agencies (SHAs) about the individual LD practices that they utilize. The research work aimed to examine estimation practices and processes. The latter includes methodologies, worksheets, design aids, and the presence of a responsible department for developing rates. The study highlighted that most agencies do not use a methodology for estimation and end up not bearing a relationship with actual anticipated damages. Moreover, the responsible department was found to be the construction bureau and design bureau in most, rather than what was preferable by the study, which is the accounting department that has the most knowledgeable personnel who compile supporting financial information [60].

Lbbs and Nguyen (2007) studied field overhead (FOH) damages and provided an alternative approach by assigning FOH costs onto scheduled activities. The proposed analytical method splits FOH costs into time related and non-time related FOH. The time related field overhead must be directly connected to the passage of time such as administration and utilities overhead. Non-time related overhead includes one-time expenses such as temporary construction, bonds or insurance. Each FOH factor is then allocated to schedule activities in direct proportion of their direct cost drivers such as labor hours and costs. Moreover, the study asserted that efforts for probable delay damage assessment must start from the beginning of project commencement [61].

Table 3 summarizes the surveyed literature concerning delay liquidated damages assessment. The aim is to understand the current state of practice of delay liquidated damages in order to perform an analogy between delay liquidated damages and green liquidated damages.

Table 4 Summary of Literature Discussing Liquidated Damages Assessment

Source	Work Title	Method
McCormic (2003)	Make Liquidated Damages Work	Owner Guidelines for LD Formation: 1. Extra cost incurred by owner due to breach 2. Lost revenue and profit per day/per breach
Crowley et al (2008)	LDs: Review of Current State of Practice	- Must follow a defined methodology to achieve a rate that reflects actual anticipated damages - Accounting department must be responsible for estimation as they compile supporting financial information
Lbbs and Nguyen (2007)	Alternative for Quantifying Field Overhead Damages	Schedule activities according to direct proportions of cost drivers (in delay case labor hrs. and labor cost) then allocate late overhead activities based on these drivers. Efforts for monitoring LDs must start from beginning.
Zech et al, (2008)	Robust Determination for LD rates for State Highway Agencies	1. Determine historical data 2. Collect and organize this data 3. Calculate workday LD rates Proposed guidelines to eliminate subjectivity and provide legal scrutiny: - Data organization - Outlier removal - Following statistical procedures to determine project-size groups
Ellis et al (1997)	Development for Improved Motorist User Cost Determinations for FDOT Construction Projects.	RUCs categorized into quantified and non-quantified factors. Quantified factors are categorized into monetary and non-monetary factors. Only quantified monetary factors are taken into consideration for calculations.

3.5.2 Liquidated Damages Conditions

3.5.2.1 LDs according to different Jurisdictions

Assaad & Abdulmalak (2020) explored different legal perspectives towards liquidated damages. The authors proposed the following guidelines to be followed by the contracting parties to have the contracted delay damages stipulated in the contract enforceable[62]:

Table 5 Guidelines for enforceable liquidated damages

	Guideline	Description
1	**Recovery not penalty**	To expressly state that the aim behind the damage provision is to compensate for damages occurred rather than penalizing the contractor for his breach
2	**Default**	Specify the exact default that would trigger the levying of the damages and to define the proper recovery mechanism.
3	**Reasoning**	Include the reasoning/calculations/formula behind determining the value of the stipulated amount at the time of contract formation
4	**Difficult estimation**	Clearly state that difficulties were faced in estimating the amount of losses to show that both parties were aware of this matter and to have their intentions expressed
5	**Synchronization of contract**	Carefully synchronize all other provisions in the contract to ensure that they don't contradict with the parties' intentions
6	**Wording**	Regardless of the effect of the terminology used on the enforceability of the clause, it is advised to avoid contract wordings related to punishment or penalty
7	**Laws**	Consider the prevailing laws in the country where the contract is executed to ensure that no regulations prevent the clause from being enforceable.

3.5.2.2 LDs according to different standard forms of contract

The recovery of liquidated damages is governed by a set of standard conditions, table 5 summarizes the standard conditions as discussed by six standard forms of contract: ConsensusDocs, AIA, EJCDC, JCT, NEC, FIDIC [54] .

Table 6 Summary of LD Enforceability Conditions in Standard Forms of Contracts

Standard Condition		Reference
Condition Precedency	**Time of levying damages**	
	When evidence for delay is present	ConsensusDocs, AIA
	When the contractor fails to perform a milestone	EJCDC, JCT, NEC, FIDIC
	Procedure	
	Three notice &certification Procedure	JCT
	Dual early warning procedure	NEC
	Engineer's Notice and Determination	FIDIC
Characteristics of Amount	Determined by parties in the **relevant clause**.	ConsensusDocs
	No concurrency: cannot claim actual damages and LD.	ConsensusDocs
	Expressed as a **rate**.	All
	Must **expressly recognize**: difficulty in estimation, sum reflects actual suffered loss.	AIA
	Shall reflect a **reasonable estimate** of future probable damages, **not a penalty**.	All
	Could be reduced by owner's notice	JCT
	LD sum and **cap** must be in appendix to tender.	FIDIC
Collection Mechanism	Owner/arch can **adjust**, **reject**, or **nullify certified payment** if reasonable **evidence** that CTR will be late.	ConsensusDocs, AIA
	Can have **retention bond** instead of retaining money.	ConsensusDocs
	Owner can impose **set-off** against any **certified progress** or final payments (following a claim) if LD are due and retainage money not enough.	EJCDC, FIDIC
	Owner can recover LD as a **debt** or **from sums due** to CTR	JCT
	PM assesses the amount **due**, and this amount includes provisions for delay damages.	NEC
Time	Pt. of recovery with respect to contract completion date:	
	Before	ConsensusDocs, AIA
	After	EJCDC, JCT, NEC, FIDIC

Moreover, Abdul Malak and Khalife (2020) studied how Sustainable Building Project's risks are addressed by contract terms of three Standard Forms of Contract: AIA, ConsensusDocs, and DBIA [33].

Table 7 Summary of the Risks Addressed by Standard Forms of Contract

AIA E204 Sustainable Projects Exhibit	**No party can insure certification achievement** Section 6.1 *"The Owner, Contractor and Architect acknowledge that achieving the Sustainable Objective is dependent on many factors beyond the Contractor 's and Architect's control, such as Owner's use and operation of the Project; the work or services provided by the Owner 's other contractors or consultants; or interpretation of credit requirements by a Certifying Authority. Accordingly, neither the Architect nor the Contractor warrant or guarantee that the Project will achieve the Sustainable Objective.*"
	Mutual Waiver of Claims Article 5: *"The owner, Contractor and Architect waive claims against each other for consequential damages resulting from failure of the Project to achieve the Sustainable Objective or one of the Sustainable Measures"*
ConsensusDocs Guidebook 310 Green Building Addendum	**Green Building Facilitator** Section 4.5 "*The GBF shall coordinate and facilitate the process of obtaining the Elected Green Status, including identifying Green Measures, alter natives and providing such other services, advice and guidance as provided in this Addendum. The GBF is not, however, assuming the role or responsibilities of the Design Professional, who shall retain responsibility for the design of the project and other services to be performed by Design Professional"* Section 8.3 "*the only party liable or responsible for the failure of the Elected Green Measures to achieve the Elected Green Status or intended benefits to the environment or natural resources including failure of the project to achieve an intended third-party certification"*
	Waiver Consequential damages section 8.2: waiver of consequential damages, while including SBP certification damages in any recovery clause stipulated in the general conditions document between owner & GBF.
	Certification LD Document 200 Section 6.5: The GBA affords the owner the option of including certification damages within LD

Table 8 (Cont'd) Summary of the Risks Addressed by Standard Forms of Contract

DBIA Sustainable Project Goals Exhibit	**Remedies that can be enforced in case of failure** Article 4 "remedies" 1. **Waiver of claims** by owner to design builder, where failure is not considered a breach of contract 2. **Certification LD**: to agree on a fixed amount of LD in case of project's failure "*to achieve other sustainable standards as are identified, or as required by the Legal Requirements, provided the Owner has fully satisfied its obligations in relation thereto"* 3. **Cure**: to agree that the design builder shall be responsible to cure such failure "*Through the addition, replacement, or correction of materials, configurations, systems, or equipment in order to in obtain the level of LEED certification"*
	Tools for Cure To control the implementation of this remedy type (cure), the exhibit clearly identifies three limits to choose from: (1) any contingency balance remaining in the design builder 's guaranteed maximum price (GMP) contract (2) the design-builder 's shares of the savings considering that the GMP is not reached (3) a fixed sum agreed upon by the parties (Prum & Del Percio 2010).

3.5.3 Summary of liquidated damages conditions

This chapter aimed at exploring owner's instruments for control over project objectives. We discussed first delay liquidated damages, then tackled performance liquidated damages, and finally introduced the concept of green liquidated damages. Later, an overview on the literature's methods for LD assessment was performed by determining the governing conditions and composition of liquidated damages. Figure 9 summarizes the main points related to liquidated damages assessment found in the literature.

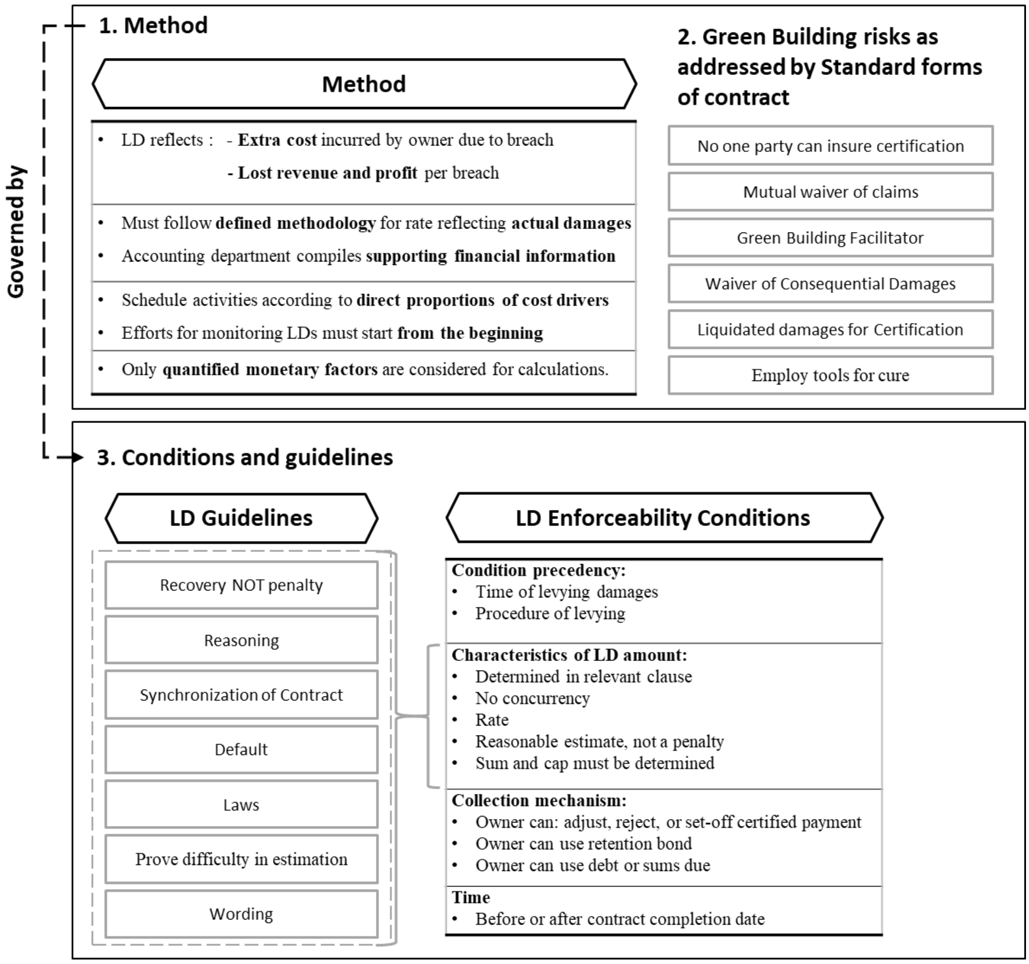


Figure 9 Summary of liquidated damages assessment guidelines found in literature

The research performed in this chapter aims to provide guidance to the recovery mechanism to be followed for assessment of GLD. Of the methods, conditions and guidelines summarized above, specific titles are chosen to be explored in depth by this research work. Namely, the chosen titles are the composition of LD sum, the rate of recovery to be followed by project stakeholders until the ceiling of damages is reached, and the recovery mechanism to be followed to ensure that the recovered sum is a reasonable estimate reflecting actual damages.

CHAPTER 4

LEED CERTIFICATION OVERVIEW, COSTS AND BENEFITS

4.1 Preamble

This chapter includes information about LEED certification; the rating systems available, the certification levels, minimum program requirements, and an overview about all the credits in LEED v4 New Construction rating system. An overview on the Literature's record of Green Building costs and benefits will be explored and summarized.

4.2 Overview on LEED Certification

LEED is the most commonly used green building rating system worldwide, it provides certification systems for almost all building types, and has become globally recognized as a symbol for achieving sustainability and leadership [63]. It has been developed by the United States Green Building Council to provide a professional benchmark for sustainable buildings and could be applied to all building phases that include new construction, interior fit outs, core and shell and operations and maintenance [1]. The first pilot program of LEED was released in 1998 as LEED v1.0. Two years later, LEED v2.0 followed, then v2.1 in year 2002, and v2.2 in 2005, after that came v2009, followed by LEED v4 in 2013, and finally v4.1 in the year 2019 [64] [65] [66].

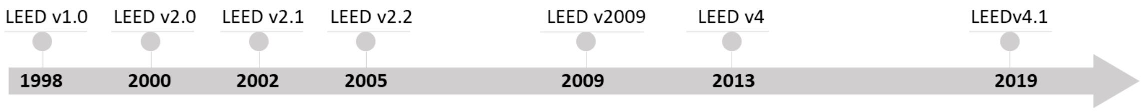


Figure 4 LEED Versions Timeline

4.2.1 LEED Certification Levels

LEED offers four certification levels, and each requires a certain number of points to be achieved. The maximum number of achievable points is 110. Table 8 below shows the number of points required to achieve each certification level.

Table 9 Number of Points Required for Each Certification Level

Certification Level	Number of Points Required
Certified	40 – 49
Silver	50 – 59
Gold	60 – 79
Platinum	80 and above

4.2.2 LEED Rating Systems

LEED provides several rating systems depending on application of the intended project. Table 9 provides a summary regarding the rating systems available.

Table 10 LEED Rating Systems and their Applications [1]

Rating System		Applications
BD+C	Building Design and Construction	New construction projects or major renovations: New construction, Core and Shell, Schools, Retail, Hospitality, Data Centers, Warehouse and Distribution Centers, Healthcare.
ID+C	Interior Design and Construction	Complete interior fit-out projects: Commercial Interiors, Retail and Hospitality
O+M	Building Operations and Maintenance	Existing buildings that undergo improvement works or little to no construction: Existing Buildings, Schools, Retail, Hospitality, Data Centers, and Warehouses & Distribution Centers.
ND	Neighborhood Development	New land development or redevelopment projects containing residential uses, nonresidential uses, or a mix. Projects can be at any stage from conceptual planning to construction: Plan and Built Project
Homes		Single family homes, low-rise multi-family (one to three stories) or mid-rise multi-family (four to six stories) homes
Cities and Communities		For entire cities and sub-sections of a city. LEED for Cities projects can measure and manage their city's water consumption, energy use, waste, transportation and human experience.
LEED Recertification		Applies to all occupied and in-use projects that have previously achieved certification under LEED – including BD+C and ID+C, regardless of their initial rating system or version.
LEED Zero		This system is for projects with net zero goals in carbon and/or resources. It is available for all LEED projects certified under the BD+C or O+M rating systems or registered to pursue LEED O+M certification.

4.2.3 LEED Minimum Program Requirements

There are three minimum program requirements to be eligible to apply for LEED Certification. They are the following:

1. Must be on a permanent location on an existing land: the condition of permanent location is set to exclude movable buildings, while prefabricated and modular structures are to be certified once installed on site. The condition of existing land allows the building to be located on previously constructed docks, jetties, piers, infill or other manufactured structures in the condition that the artificial land was not constructed for the purpose of the LEED project by the owner [67].

2. Must use reasonable LEED boundaries: this requirement is set to ensure that the project is properly evaluated, as it requires the boundaries to include all land contiguous to the project and supports its typical operations. Consequently, project boundaries submitted to LEED must not exclude parts of the building that could result in a disadvantage of not complying with credit requirements [68].

3. Must comply with project size requirements: the table below shows minimum size requirements of each certification type [69]:

Table 11 Minimum Size Requirements for LEED Rating Systems [7]

Rating System	Minimum Size Requirement
LEED BD+C and O+M: Existing Buildings	93 m^2
LEED ID+C and O+M: Interiors	22 m^2
LEED Neighborhood Development	At least two habitable buildings & no larger than 1500 acres
LEED Residential Single Family Homes	Must be defined by “dwelling unit” by all applicable codes.

4.2.4 LEED v4 Categories and Credits

This research focuses on LEED BD+C New Construction version v4. This version of the rating system requires the achievement of 10 prerequisites and 44 credits distributed across 9 categories. The total number of achievable points is 110.

Table 12 Brief on the requirements of each LEED credit

		Credit	Points	Brief Requirement
	IP	Integrative Process	1	To have project parties work synergistically on the project starting from the pre-design phase in order to satisfy all owner project requirements, establish basis of design, and have well established design documents and construction documents.
Location and Transportation	LT1	LEED for Neighborhood Development Location	16	To have the project located within a boundary of a development certified under LEED for Neighborhood Development. When projects attempt this credit, they can no longer earn other LT Points.
	LT2	Sensitive Land Protection	1	In the aim of reducing the environmental impact of the project, the project must be located on a previously developed site or on a land considered non-sensitive that fall under USGBC's definition of prime farmland, floodplains, habitat, water bodies, or wetlands.
	LT3	High Priority Site and Equitable Development	2	The first option is to locate the project in a high priority site, which could be either an economically disadvantaged community location, or a brownfield remediation (soil or groundwater contamination identified and remediation is required). The second option is to locate it in an equitable development which requires either the development and implementation of an equity plan, or to provide affordable housings in residential or mixed-use projects.

		Credit	Points	Brief Requirement
Location and Transportation	LT4	Surrounding Density and Diverse Uses	5	Locate the site in a dense area or to have it in an area with close access to diverse uses according to USGBC's specifications to this credit.
	LT5	Access to Quality Transit	5	To have the project within USGBC's distance access limits to public transit service or project- sponsored transit service.
	LT6	Bicycle Facilities	1	Design or locate the project close to bicycle network, and bicycle storage and shower rooms.
	LT7	Reduced Parking Footprint	1	To abide by minimum local code requirements related to parking capacity (not more), or dedicate parking spots for car share vehicles, or unbundle the parking spaces (sell separately or charge equal to a roundtrip cost).
	LT8	Green Vehicles	1	Provide supply equipment for electric vehicles, or an infrastructure ready for electric vehicles which includes a dedicated electric circuit with sufficient capacity for each required space.
Sustainable Sites	SSP	Construction Activity Pollution Prevention	Required	Create and implement an erosion and sedimentation plan for all the contraction activities related to the project in conformance to requirements associated to this credit.
	SS1	Site Assessment	1	Perform and document a site survey or assessment that must include information regarding topography, hydrology, climate, vegetation, species, soils, human use, human health effects.
	SS2	Site Development - Protect or Restore Habitat	2	To preserve and protect 40% of the greenfield are on site from all developments and ongoing construction activities. In addition, must restore a portion of the site by performing defined vegetation and soil requirements.
	SS3	Open Space	1	Provide outdoor space area not less than 30% of total site area, where 25% of this area must be vegetated or have overhead vegetated canopy.
	SS4	Rainwater Management	3	In the first option, points are granted depending on the percentile of rainfall retained. The other option compares the runoff resulting from the development and runoff generated in natural conditions, then requires the development to be able to retain the difference between these two values.
	SS5	Heat Island Reduction	2	The first option requires the satisfaction of an equation requirements related to roof and non-roof measures that reduce heat island effect (reflectance material and vegetated roof), the second option requires that a minimum of 75% of spaces be under cover with specific cover requirements.
	SS6	Light Pollution Reduction	1	Must meet up light and light trespass requirements by using either the calculation method or the backlight-up light-glare method as defined in the USGBC requirements for this credit.
Water Efficiency	WEP	Outdoor Water Use Reduction	Required	To reduce outdoor use reduction by either having no irrigation required, or by reducing landscape water reduction by at least 30%.
	WEP	Indoor Water Use Reduction	Required	Concerning building water use, reduce aggregate water consumption by 20% from the baseline for the fixtures and the fittings. In addition, install appliance and process water use that meet with USGBC's requirements for this credit.
	WEP	Building-Level Water Metering	Required	Install permanent water meters to monitor the total potable water use for the building and submit to USGBC monthly and annual summaries of this data spanning a duration of five years.
	WE1	Outdoor Water Use Reduction	2	To have either a landscape that does not require irrigation beyond a two-year establishment period, or reduced irrigation by at least 50% from the calculated baseline for the site’s peak watering month.
	WE2	Indoor Water Use Reduction	6	to further reduce fittings and fixture's water use from the baseline's reduction where points depend on a table provided by USGBC.
	WE3	Cooling Tower Water Use	2	The first option requires, for the cooling tower and evaporative condenser cycles of concentration, a one-time potable water analysis that measures at least the listed five control parameters. The second option requires to optimize water use for cooling. The third option requires a minimum of a certain percent for the use of recycled alternative water to meet process water demand.
	WE4	Water Metering	1	Install permanent water meters for two or more of a list of water subsystems as applicable to the project.

		Credit	Points	Brief Requirement
Energy and Atmosphere	EAP	Fundamental Commissioning and Verification	Required	Must fulfill requirements for commissioning Cx process activities for mechanical, electrical, plumbing, and renewable energy systems and assemblies.
	EAP	Minimum Energy Performance	Required	Compliance with ANSI/ASHRAE/IESNA Standard 90.1–2016, with errata or a USGBC-approved equivalent standard provisions.
	EAP	Building-Level Energy Metering	Required	Install building-level energy meters, whose results can be compiled to provide building-level data representing total building energy consumption. Must commit to share energy data with USGBC for a five-year period.
	EAP	Fundamental Refrigerant Management	Required	Must not use chlorofluorocarbon (CFC) or hydro chlorofluorocarbons (HCFC)- based refrigerants in any HVAC and refrigeration systems. Must submit a phase out plan in case the HVAC&R equipment are reused.
	EA1	Enhanced Commissioning	6	The team must implement or have a contract with a different entity to implement certain commissioning process activities in addition to those required by the EA prerequisite.
	EA2	Advanced Energy Metering	1	Install advanced energy metering for the whole-building energy sources and individual energy end uses that make-up more than 10% of the total annual building energy consumption. The advanced energy meters must compile to a list of characteristics.
	EA3	Demand Response	2	Have the building equipment capable of being incorporated in demand response programs that include load shedding or shifting.
	EA4	Renewable Energy Production	3	Install on-site renewable energy systems or procure from offsite sources renewable energy for all or part of the building's energy use. Procurement could either be a built generation asset off-site or purchasing Green-e Energy certification or equivalent.
	EA5	Enhanced Refrigerant Management	1	Eliminate the use of refrigerants in HVAC&R systems or, for option 2, have the combination of all new and existing base building and tenant systems serving the project comply with a determined formula.
	EA6	Green Power and Carbon Offsets	2	Engage in a five-year contract insuring that 50% (1point) or 100% (2points) of the project's energy to be from green power, carbon offsets, or renewable energy certificates (RECs) from a green-e certified source.
	EA7	Optimize Energy Performance	18	Analyze efficiency measures from the beginning of the design phase focusing on load reduction and HVAC-related strategies. The number of points earned depends on the percentage improvement in energy performance.
Materials and Resources	MRP	Storage and Collection of Recyclables	Required	Must allocate dedicated areas for the storage and collection of recyclables in addition to appropriate measures for the appropriate collection, storage and disposal of two of the following: batteries, mercury containing lamps, and electronic waste.
	MRP	Construction and Demolition Waste Management Planning	Required	No smoking inside the building and outside the building by at least 7.5 meters from all entries. For residential units, an option of compartmentalization of smoking areas is also available.
	MR1	Building Life-Cycle Impact Reduction	5	Achieve reduced environmental effects through either reusing the building or its materials or by performing a whole-building life-cycle assessment that includes a cradle-to-grave life-cycle assessment that yield a certain percentage reduction for defined impact categories compared to a baseline building.
	MR2	Building Product Disclosure and Optimization - Environmental Product Declarations	2	The first option is environmental product declaration where one must choose at least 20 different permanently installed products sourced from different manufacturers such that they meet the listed disclosure criteria. The second option is to have at least 10% of products by cost or 10 permanently installed products comply with criteria of embodied carbon optimization.
	MR3	Building Product Disclosure and Optimization - Sourcing of Raw Materials	2	Use products sourced from at least 3 or 5 different manufacturers for at least one of a list of responsible sourcing and extraction criteria for at least 20% or 40% by cost of the total value of permanently installed building products of the project.

		Credit	Points	Brief Requirement
Material and Resources	MR4	Building Product Disclosure and Optimization - Material Ingredients	2	The first option is material ingredient reporting, it includes using at least 20 permanently installed products from at least five manufacturers and prove that their chemical content is less than 0.1%. The second option is material ingredient optimization, where one must use permanently installed products from at least three different manufacturers that document their material ingredient optimization using defined paths.
	MR5	Construction and Demolition Waste Management	2	Must develop and report a construction and demolition waste management plan where points are achieved through waste prevention/ or diversion. The report must include defined key points
Indoor Environmental Quality	IEQP	Minimum Indoor Air Quality Performance	Required	For mechanically ventilated spaces, meet the requirements of a defined ASHRAE standard and provide outdoor air monitors for all mechanical ventilation systems. For naturally ventilated spaces, one of three ASHRAE natural ventilation paths could be followed.
	IEQP	Environmental Tobacco Smoke Control	Required	Either prevent or reduce smoking in all internal spaces and for external spaces at a distance not less than 7.5 m from the entrance
	IEQ1	Enhanced Indoor Air Quality Strategies	2	Must comply with either 3 strategies to gain one point or 6 strategies to gain 2 points. The strategies are: Entryway systems, Interior cross-contamination prevention, filtration of outdoor air, filtration of recirculated air, increased ventilation of 15% or 30%, operable windows, engineered natural ventilation, carbon dioxide monitoring, and additional source control and monitoring.
	IEQ2	Low-Emitting Materials	3	To use materials on the building interior that meet defined low-emitting criteria.
	IEQ3	Construction Indoor Air Quality Management Plan	1	Develop and implement an indoor air quality (IAQ) management plan for the construction and preoccupancy phases of the building. Plan must include a list of defined criteria.
	IEQ4	Indoor Air Quality Assessment	2	Must perform one of two options to be implemented upon construction completion and when all systems are installed. The first option is to have a flush out either before occupancy or after it. The second option is to perform air testing on particulate matter and inorganic gases and/or volatile organic compounds.
	IEQ5	Thermal Comfort	1	Must meet the requirements of thermal comfort design and thermal comfort control as defined by this credit's criteria.
	IEQ6	Interior Lighting	2	The available strategies are glare control, color rendering, lighting control and surface reflectivity. Meeting one earns the project 1 point, meeting 3 earns it 2 points.
	IEQ7	Daylight	3	Provide manual or automatic glare-control devices for all regularly occupied spaces and select one of three options: simulation for spatial daylight autonomy and annual sunlight exposure, simulation for illuminance calculations, illuminance measurements.
	IEQ8	Quality Views	1	provide occupants to outdoor natural or urban environment for 75% of all regularly occupied area.
	IEQ9	Acoustic Performance	1	Must meet two of the following: HVAC background noise, Sound Transmission, and/or Reverberation time, for all occupied spaces.
Innovation	IN1	Innovation	5	Must achieve at least one pilot credit, at least one innovation credit and no more than two exemplary performance credits in order to achieve all five points.
	IN2	LEED Accredited Professional	1	Must have at least one of the project team a LEED Accredited professional with a specialty appropriate for the project.
Regional Priority	RP	Regional Priority: Specific Credit	1	A defined database for the regional priority credits and their geographic location is provided by the USGBC website. Project teams could earn up to four points by achieving credits that have regional importance for their project's region.
	RP	Regional Priority: Specific Credit	1	
	RP	Regional Priority: Specific Credit	1	
	RP	Regional Priority: Specific Credit	1	

4.3 Green Building Premium

Integrating sustainability practices into a construction project represents an investment performed by project owners. One of the most comprehensive studies on green building costs and benefits indicates that an initial investment of 2% of construction costs could yield life cycle savings of more than 10 times the initial investment [14]. Several studies have been performed to assess the premium paid upon seeking LEED certification. It could be in the form of soft costs or hard costs.

In general, soft costs are distributed into four main categories. The first is the design premium. Second, LEED requires hiring an outside team to ensure compliance of fundamental building systems and elements to the guidelines set by LEED. The third factor, documentation, creates a significant burden to the project; it requires a system of a tracking and reporting information and material sourcing, and is affected by the documentation team's expertise and the size of the project. The fourth factor is the energy modeling of the project; it requires hiring someone with modeling software experience to be able to satisfy the conditions of certain credits. No direct benefits result from this type of cost other than being a requirement to achieve certification. [70].

Hard costs require the installation of alternative greening systems that improve the efficiency of the building, generate energy, or satisfy the requirements of certain credits. Determining the premium of these costs varies depending on the LEED certification level, criteria selected, and the local code requirements. The latter could be effective since certain areas have several requirements that conform with LEED requirements, and consequently do not incur extra costs. Whereas other areas have minimal code requirements that make the process of achieving LEED certification a remarkable increase to the project's costs.

A report performed by Northbridge Environmental Management Consultants in 2003 determined that the project's construction cost can be increased by 4% up to 11% upon seeking LEED Certification, where more than half of these costs, which is around 3 to 8%, goes to greening investments, and the remaining cost, which is round 1 to 3%, are attributable to "soft costs". Of the soft costs 0.4 up to 0.6 % of construction costs were attributed to design premiums. Commissioning costs were estimated to range between 0.5 to 3% of construction costs, and documentation costs were set to range between 0.5 to 0.9 % of construction costs. Finally, according to estimates of R.S. Means and an environmental and consulting design firm, the report estimated energy modeling cost as 0.1 % of construction cost [70].

Moreover, in an article by Nikolow in 2008, the author discussed the cost premium for LEED certification. Among estimation of soft costs, commissioning fees could range from USD2.5 per square foot for small projects to USD0.3 per square foot for large projects. Moreover, energy modelling services and documentation were determined to range between USD15,000 and USD50,000, increasing with project size and complexity, whereas LEED registration costs USD600 and certification fees range between USD2,250 and USD22,500 depending on project size. [71]

In 2011, an article written by Vamosi also explored the extra costs incurred by LEED design. LEED registration fees were stated as USD900, and LEED certification fees were determined as USD2,900 for buildings smaller than 50,000 square feet and USD20,000 for buildings exceeding 50,000 square feet. The author estimated that construction-related expenses could add a premium of 10 to 30%. Furthermore, a green design professional could charge an extra 10 to 15% to his fee for reporting and monitoring building performance. [22]

In 2003 as well, a report published by the Kansas Emergency Management Association explored cost factors associated with four building types, which were mainly k-12 schools, laboratories, libraries and multi-family affordable housings. The report came out with LEED premium estimates as 0 to 2.5% for Certified, 0 to 3.3% for Silver Certification, 0.5 to 5 % for Gold Certification and 4.5 to 8.5% for Platinum Certification [72].

A 2006 analysis of costs and benefits of 30 schools built to LEED standards indicated a cost premium ranging between 0% and 6.27% [73]. Moreover, according to World GBC's green building report published in 2013, cost premiums for green buildings typically range between 0 and 12.5%, such that LEED Certified ranges between 0% and 4%, LEED Silver and Gold levels range between 0% and 10%, and LEED platinum ranges between 2 and 10%[74].

A 2015 analysis performed on a sample of 160 LEED certified buildings found that the cost premium of LEED certified buildings ranges from 2.5 to 9.4% with an average of 4.1% [75]. Whereas a study performed in 2016 by Dwaikat and Ali stated that

90% of the reviewed 17 empirical studies reported a cost premium range of -0.4% to 21% [76].

Figure 12 summarizes the cost premium ranges of the reviewed literature.

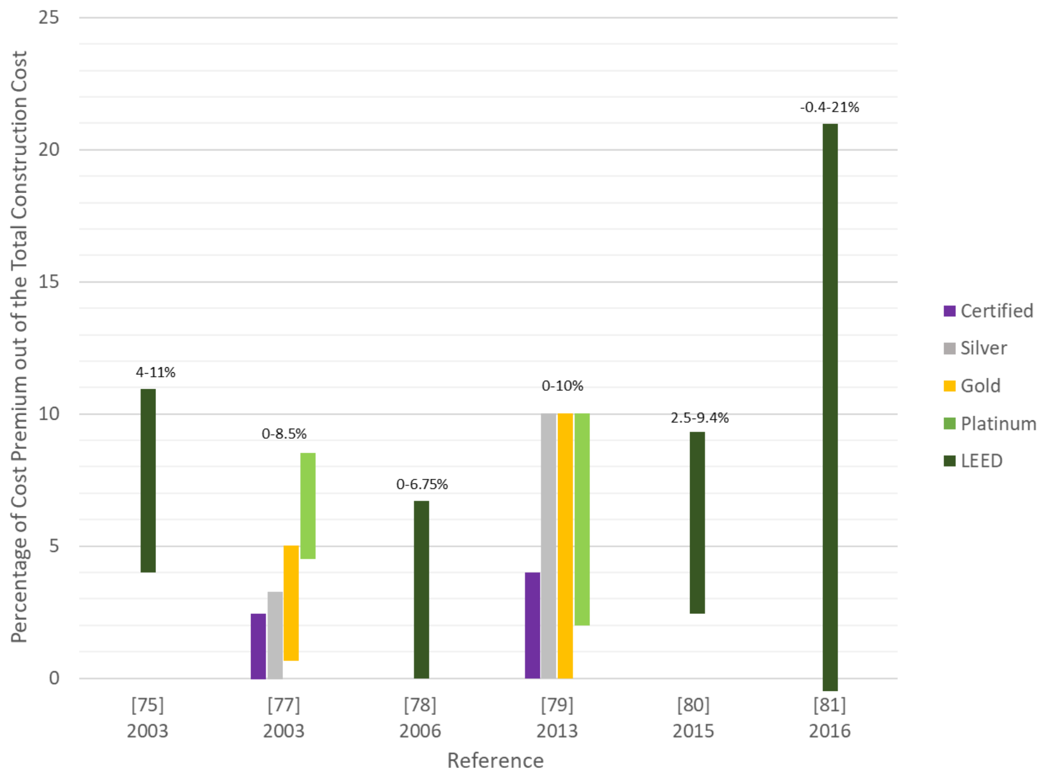


Figure 5 Summary of LEED Certification Premiums

4.4 Green Building Benefits

Green buildings have various benefits that encourage people to pay a premium in order to attain. These could be measured and quantified such as financial benefits, operational advantages, benefits related to occupants and environmental benefits. Moreover, unquantified benefits are also present and play a good role in motivating developers to pursue certification. Of the unquantified benefits we mention marketing advantages, environmental and social benefits, and the better wellbeing of residents.

4.4.1 Green Building Quantified Benefits

Green buildings could achieve financial benefits such as an increase in price premium of up to 30% [77], or higher to up to 34% [78]. Rent premiums could reach up to 17.3% and the occupancy rate can increase till 23.1% [77]. Moreover, the return on investment can be improved by 19.2% for existing green projects and 9.9% on average for new projects; PNC Bank’s LEED-certified branches are an example where they brought in USD3M more in customer deposits and originated 25.5% more consumer loans annually [79]. Most importantly, asset value is observed to increase by 9% to 10% [80], [78].

Green Buildings have operational advantages that could be quantified and further translated into monetary values. One of the main attributes of green building operational benefits is the savings on energy consumption; green buildings are reported to save up to 25% in energy consumption [79] [81], or even up to 30% for LEED Certified and LEED Silver, approximately 48% for LEED Gold, and up to 60% for LEED Platinum [80]. To be more specific, one of the factors for the reduction of energy consumption is related to the installed HVAC systems that are reported to have reduction in consumption of 39.6% up to 90%. In addition, site energy consumption is reported to have 10% to 15% reduction in some cases and 25% to 30% reduction in others, while energy savings due to daylight presence could achieve reduction of 25% up to 90% [77]. Another major operational advantage is savings in water consumption. According to the U.S. Department of Energy, LEED certified buildings report 11% less water consumption [79] [81], and this value could reach up to 32% depending on other sources [77].

Green buildings have some benefits that can be quantified in numbers or measured but are not translated into monetary factors. Of these we mention the reported better productivity occupants experience; productivity could be enhanced by 0.2% up to 15% by a set of 14 studies, or even higher at a range of 0.7% up to 26.1% as reported by 11 studies [77]. Moreover, quality views and natural daylight have provided facility workers and employees with better working environments that workers reported 25% better performance in recalling tasks [82]. Concerning the health impact, 17 studies reported 13.5% up to 87% health improvements that directly relate to enhanced air quality [77]. Air quality related illnesses witnessed improvements reaching up to 50% [82]. Moreover, research indicates that better working and living environments yield 27% reduction in incidences of headaches, which account for 0.7% of overall cost of employee health insurances; estimated as approximately USD70 per employee annually [79].

Most importantly, green buildings have notable quantified environmental advantages. According to a review by the U.S. Department of Energy on 22 LEED certified buildings, the sample under study achieved a 34% reduction in CO_2 emissions [79]. According to estimates performed by the World Green Building Council, the potential for reduction in CO2 emissions is as much as 84 gigatons ($GtCO_2$) by the year 2050 [13]. In addition, sources have indicated that more than 80 million tons of waste were diverted away from landfills by green buildings, a number inspected to increase to 540 million tons by 2030 [80].

4.4.2 Green Building Unquantified Benefits

Green buildings have unquantified effects that can neither be translated into monetary factors nor be measured in real figures. What can be performed to correlate and understand these benefits is to relate them to relevant indicators. For example, the occupant wellbeing can be related to their satisfaction with the building. According to a survey released by the USGBC, more than 90% of respondents said that they are satisfied with their job, whereas 79% of respondents said that they would take a job in a LEED certified building over a non-certified [13]. Moreover, the access to better air quality, natural sunlight and quality views contributes to the occupant's happiness and boosts their productivity as reported by 80% of the surveyed respondents, and 80% said that the enhanced air quality improved their physical health [13].

Another unquantified effect is the marketing benefits achieved upon earning certification. A study performed by Matisoff et al (2007) realized that the largest number of buildings cluster at the certification level, which proves that they focus on the marketability of the target certification level rather than the performance of the green building. To further clarify their argument, the authors analyzed the achieved certification level depending on the developer; governments do not tend to signal Gold or Platinum levels, college campuses tend to signal Gold and Platinum, profit firms and restaurant tend to signal all levels, hotels and resorts tend to signal Platinum levels exclusively, while commercial buildings tend to signal Silver and Platinum Levels [83]. A research performed by Berger (2019) aimed to test the green signaling hypothesis, which indicates that green products can provide a signaling benefit that acts as an incentive for consumers to pay more for their green product. The results of the research work realized that participants in the study had a higher willingness to pay when their purchase of green products was performed publicly rather than in private, since green signalers are better treated publicly [84].

Finally, green buildings have various unquantified environmental and social benefits that can be a consequential advantage of all the factors elaborated earlier. Of these we mention a decrease in global warming, less endangered species and ecosystems, improved social welfare, and reduced poverty.

Figure 13 summarizes all the mentioned green building benefits.

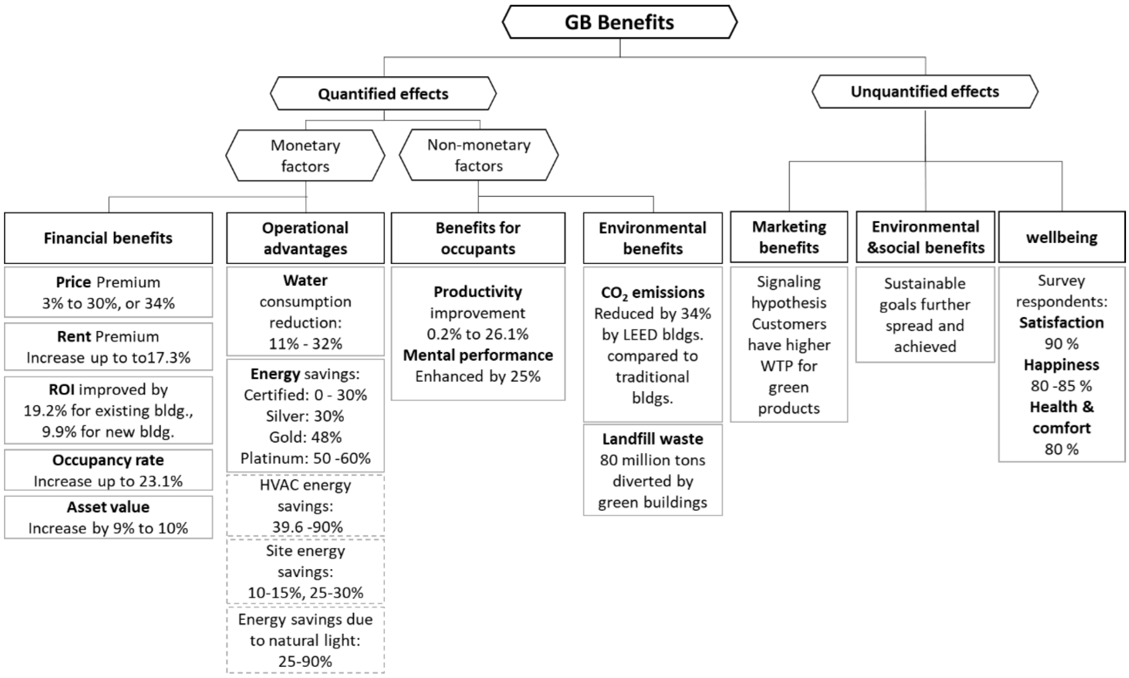


Figure 6 Summary of Green Building Benefits

4.5 Government's regulations related to green buildings

One of the impediments faced by green building developers is that green buildings have high capital costs without providing benefits at the early stage of project implementation. Financial returns start to emerge towards the end of the project and during operation phase [85]. This drove many governments to put regulations into action to motivate developers to implement green buildings; thus removing the barrier to the "affordability" of high green building premiums [85]. Moreover, most green building incentive programs use a "tiered benefit system" that provides more reward for higher certification levels [86]. These incentives can be classified into two main categories: direct monetary incentives and intangible incentives [87].

4.5.1 Direct monetary incentives

Direct monetary incentives include the waiver of fees, refunds or fee reductions, providing tax incentives, and other incentive programs [87].

4.5.1.1 Fee waiver/ refund/ reduction

Municipalities typically charge a fee for reviewing and issuing permits. To motivate green buildings, some municipalities offer a fee waiver for green building projects [85]. For example, Chicago, Illinois, has been following a Green Permit Program since 2005 that provides expedited permitting for commercial and residential sectors, in addition to offering up to 100% waiver for consultant review fees for LEED certified projects [87]. Moreover, Mecklenburg county in North Carolina offers a Green Permit Rebate Program that offers reductions for LEED certified projects where LEED Certified projects receive a 10% reduction, LEED Silver projects get a 20% reduction, LEED Gold projects get a 25% reduction, and LEED Platinum projects get a 25% reduction [87].

4.5.1.2 Tax incentives

Two forms of tax incentives are available in the field of green buildings: tax credits and tax abatements. Tax abatements usually reduce or remove a certain amount of the tax for a specific amount of time [87]. Whereas tax credits reduce liability of taxes in a dollar to dollar form, and these credits can later be applied to specified types of taxes that are claimable over a specified amount of time [87].

4.5.1.3 Other monetary incentive programs

Some municipalities follow a feebate program that basically works to encourage a desired behavior by discouraging the undesired one; the municipality requires all developers to participate in a certain type of fund and only green building developers are granted a refunds on their contributions [87]. The rest of the fund money is used to support green education programs or other incentives. In addition, some utilities offer reductions on services, such as water or energy, in exchange of constructing green building facilities [87]. Finally, some cities offer monetary grants for projects that implement innovative approaches into their green buildings.

4.5.2 Intangible incentives

Intangible incentives offered to green building projects include enhanced permitting and review processes, granting density bonus in relation to floor to area ratio or building height, and free marketing and advertising services.

4.5.2.1 Expedited permitting and review

Since permitting processes could take a long duration by some municipalities, a significant reduction in duration could lead to cost savings and significant schedule improvements to the project [88]. This incentive can be achieved by shifting permitting priorities without imposing extra costs on municipalities. In order to be eligible to benefit from this incentive, applicants must demonstrate compliance with a certain certification system, where the extent of reductions is dependent on the level of certification [85]. For example, higher certification levels in a LEED certified project, such as Gold or Platinum, could gain shorter permit durations. For instance, Chicago, Illinois, offers an enhanced permitting process in addition to reductions for consultant fees for green building applicants [87]. Upon submitting to the program and getting accepted, commercial projects that earn LEED Certified or LEED Silver receive the permit in less than 30 days, while Gold and Platinum projects get a more reduced duration of around 15 days [87].

4.5.2.2 Density Bonuses

Another intangible incentive strategy is the density and height bonuses for green buildings. The municipality allows for an increase in floor to area ratio, height bonus, or other density parameters beyond the underlying zoning conditions for projects that achieve green certification or equivalent [87], [88]. This incentive is very attractive for developers since it increases the asset value and allows the owner to achieve more rentals [87]. For example, the county of Arlington in the US offers floor to area (FAR) bonuses that range from 0.15 FAR for LEED Certified projects, 0.25 FAR for LEED Silver projects, 0.35 FAR for LEED Gold projects, and 0.5 FAR bonus for Platinum certified projects [86]. Moreover, the city of Germantown, Tennessee, directed the incentive program towards granting extra building height, and that was based on the developers' desires [87]. In two areas of its Smart Growth Zoning District, Germantown allows up to one story above the maximum allowed height limit in that district [87].

4.5.2.3 Publicity and awards

Some cities offer marketing and advertising incentives for projects that commit to build according to LEED certification requirements [87]. The most common marketing instruments used by cities include marketing on public signage, adding the project to green building web pages of the city, and using media tools such as broadcasts and press releases to market the project [85]. For example, the city of Gainesville, Florida, allows developers to place building signs that designate the project as being part of the city's green building program, permits the project to use the city's green building program logo on its brochures and its marketing materials, and grants it the eligibility to win the "Green Building Award" that the city provides annually to each of its various development subgroups [87].

4.5.3 Compliance to green building incentive requirements

An interesting question arises on the course of action that the government takes when a project benefitting from green building incentives fails to achieve the required certification [85]. Several sanction models have been developed for these cases depending on the type of incentive offered. In the case of expedited permitting, certification documentation showing the project's commitment to certification is required prior to the project's acceptance into the program. On the other hand, tax incentives are put on hold until the completion of the project and the required certification is met [87].

Other incentives must be implemented prior to the end of construction. In this case, more complex procedures must be followed. Bonus incentives require developers to associate a bond or letter of credit to their bonus applications that are claimed by the local governments in case the development fails to comply upon completion [85]. The amount of letter of credit or bond is calculated based on the benefit that the developer can achieve as a result of this bonus, which is the area that the bonus grants multiplied by the rental rate in that area [87]. Other cities may prevent the issuance of the certificate of occupancy or fine a certain amount of money in case green building certification is not met [87]. Pasadena, California allocates a green building official responsible to follow up on green projects and ensure their compliance to the green building certification that they are applying to; he reviews the application process, oversees the construction process and is eligible to stop the works in case an evidence for noncompliance in present. In case the requirements were not met, the official is requested to determine if the applicants are performing in good faith concerning their efforts of compliance. Good faith depends on the availability of green building materials and technologies, the market accessibility to recycle materials, and the presence of documented proof of the applicant’s efforts to comply [87].

CHAPTER 5

FACTORS GOVERNING ACHIEVED GREEN CERTIFICATION

5.1 Preamble

This chapter aims to analyze the credits achieved by LEED certified projects depending on the earned certification level. USGBC data regarding a sample group of LEED certified projects is used to understand the different combinations of credits achieved by projects of different certification levels. This analysis determines which credits must be achieved to secure a certain certification level. Consequently, these credits become the indicators for failure in case the desired certification level is not achieved.

5.2 Data Sources

The United States Green Building Council's website provides public access to information regarding registered and certified LEED projects. A filter can be performed to extract the projects that comply to desired criteria. For the analysis intended by this research work, the following filters were applied:

- Rating System: LEED BD+C: New Construction
- Rating Version: v4

Then, a filter was applied to extract each certification level at a time. The total number of projects is 349, and they are distributed into the following:

Table 13 Number of projects in each certification level (LEED BD+C NC v4)

Certification level	Certified	Silver	Gold	Platinum
Number of projects	78	99	142	30

The USGBC website provides, for each project, the achieved LEED scorecard. Also called a project checklist, the LEED scorecard shows the number of points achieved across each credit by the project. Figure 15 below shows an unfilled scorecard for LEED BD+C New Construction rating system v4 as downloaded from the USGBC website.

For each project, the scorecard was downloaded, and the number of points achieved by each credit was extracted. Eventually, the data collected included a list of all projects specifying, for each, the project name, certification level and number of points achieved in each credit across the 8 categories. This data provides information regarding the credits achieved by LEED projects of different certification levels. The following subsection provides theoretical background on the statistical analysis tools used to analyze the data at hand. The aim behind statistical analysis is to determine the credits that have statistically significant difference in achievement among the different certification levels which are Platinum, Gold, Silver and Certified certifications.

LEED v4 for BD+C: New Construction and Major Renovation
Project Checklist

Project Name:
Date:

Y	?	N	Type	Credit	Points
			Credit	Integrative Process	1

Y	?	N	Type	Location and Transportation	16
0	0	0		**Location and Transportation**	**16**
			Credit	LEED for Neighborhood Development Location	16
			Credit	Sensitive Land Protection	1
			Credit	High Priority Site	2
			Credit	Surrounding Density and Diverse Uses	5
			Credit	Access to Quality Transit	5
			Credit	Bicycle Facilities	1
			Credit	Reduced Parking Footprint	1
			Credit	Green Vehicles	1

Y	?	N	Type	Sustainable Sites	Points
0	0	0		**Sustainable Sites**	**10**
Y			Prereq	Construction Activity Pollution Prevention	Required
			Credit	Site Assessment	1
			Credit	Site Development - Protect or Restore Habitat	2
			Credit	Open Space	1
			Credit	Rainwater Management	3
			Credit	Heat Island Reduction	2
			Credit	Light Pollution Reduction	1

Y	?	N	Type	Water Efficiency	Points
0	0	0		**Water Efficiency**	**11**
Y			Prereq	Outdoor Water Use Reduction	Required
Y			Prereq	Indoor Water Use Reduction	Required
Y			Prereq	Building-Level Water Metering	Required
			Credit	Outdoor Water Use Reduction	2
			Credit	Indoor Water Use Reduction	6
			Credit	Cooling Tower Water Use	2
			Credit	Water Metering	1

Y	?	N	Type	Energy and Atmosphere	Points
0	0	0		**Energy and Atmosphere**	**33**
Y			Prereq	Fundamental Commissioning and Verification	Required
Y			Prereq	Minimum Energy Performance	Required
Y			Prereq	Building-Level Energy Metering	Required
Y			Prereq	Fundamental Refrigerant Management	Required
			Credit	Enhanced Commissioning	6
			Credit	Optimize Energy Performance	18
			Credit	Advanced Energy Metering	1
			Credit	Demand Response	2
			Credit	Renewable Energy Production	3
			Credit	Enhanced Refrigerant Management	1
			Credit	Green Power and Carbon Offsets	2

Y	?	N	Type	Materials and Resources	Points
0	0	0		**Materials and Resources**	**13**
Y			Prereq	Storage and Collection of Recyclables	Required
Y			Prereq	Construction and Demolition Waste Management Planning	Required
			Credit	Building Life-Cycle Impact Reduction	5
			Credit	Building Product Disclosure and Optimization - Environmental Product Declarations	2
			Credit	Building Product Disclosure and Optimization - Sourcing of Raw Materials	2
			Credit	Building Product Disclosure and Optimization - Material Ingredients	2
			Credit	Construction and Demolition Waste Management	2

Y	?	N	Type	Indoor Environmental Quality	Points
0	0	0		**Indoor Environmental Quality**	**16**
Y			Prereq	Minimum Indoor Air Quality Performance	Required
Y			Prereq	Environmental Tobacco Smoke Control	Required
			Credit	Enhanced Indoor Air Quality Strategies	2
			Credit	Low-Emitting Materials	3
			Credit	Construction Indoor Air Quality Management Plan	1
			Credit	Indoor Air Quality Assessment	2
			Credit	Thermal Comfort	1
			Credit	Interior Lighting	2
			Credit	Daylight	3
			Credit	Quality Views	1
			Credit	Acoustic Performance	1

Y	?	N	Type	Innovation	Points
0	0	0		**Innovation**	**6**
			Credit	Innovation	5
			Credit	LEED Accredited Professional	1

Y	?	N	Type	Regional Priority	Points
0	0	0		**Regional Priority**	**4**
			Credit	Regional Priority: Specific Credit	1
			Credit	Regional Priority: Specific Credit	1
			Credit	Regional Priority: Specific Credit	1
			Credit	Regional Priority: Specific Credit	1

Y	?	N		TOTALS	Possible Points: 110
0	0	0		**TOTALS**	**Possible Points: 110**

Certified: 40 to 49 points, **Silver:** 50 to 59 points, **Gold:** 60 to 79 points, **Platinum:** 80 to 110

Figure 7 LEED Scorecard, BD+C New Construction v4

5.3 General Observations on LEED Credit Data

As previously mentioned, the collected data provides information on the credits achieved by each project for all 349 LEED certified projects under BD+C New Construction version 4. A primary observation is set to visualize the total number of points achieved by projects in different certification levels. It is interesting to note that most projects aim to achieve a total number of points close to the threshold of the certification level. In LEED Certified, almost 70% of the projects achieved between 40 and 43 points, in LEED Silver around 80% of projects achieved between 50 and 53 points, 63% of LEED Gold projects attained between 60 and 63 points, and 60% of LEED Platinum projects achieved between 80 and 83 points. The figures below show the distribution of the percent of projects achieving each number of points.

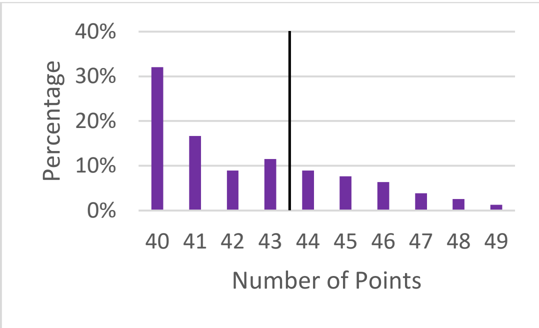


Figure 8 Percentage of projects with respect to number of points achieved for Platinum-certified projects

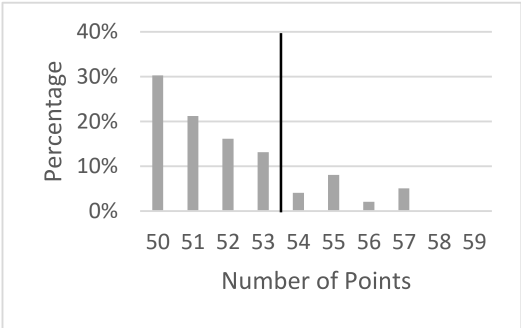


Figure 9 Percentage of projects with respect to number of points achieved for Gold-certified projects

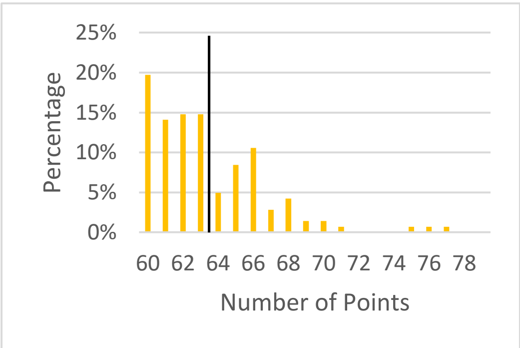


Figure 10 Percentage of projects with respect to number of points achieved for Silver-certified projects

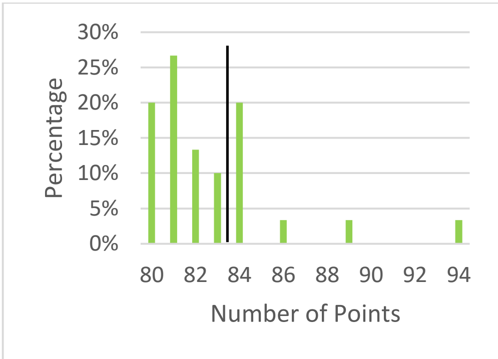


Figure 11 Percentage of projects with respect to number of points achieved for Certified projects

Furthermore, a basic analysis was performed to visualize the pattern of credit achievements across different certification levels. Figure 19 shows a plot for the percent of projects that achieved each credit across the four certification levels. It is noted that the number of points achieved is not incorporated yet, but merely whether the credit is achieved or not.

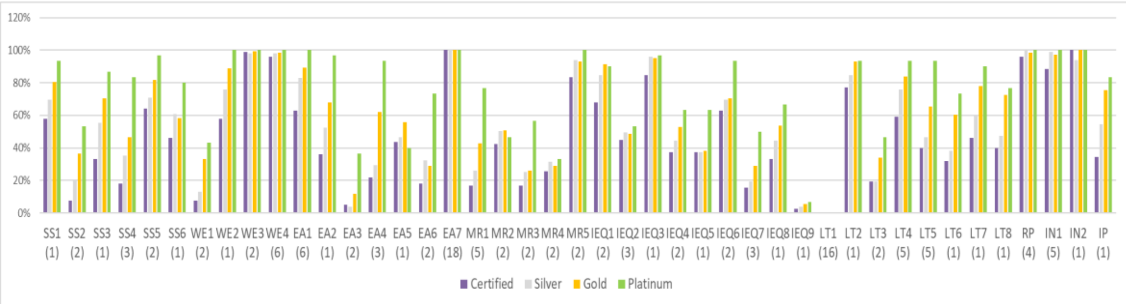
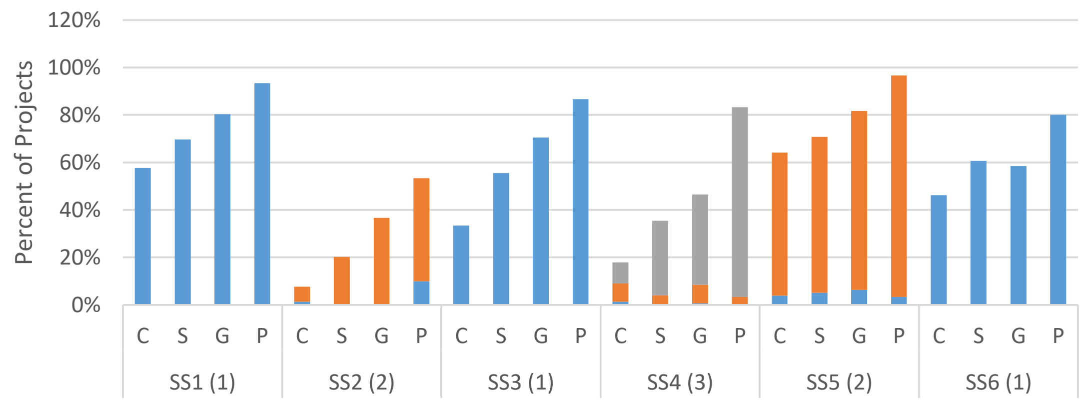


Figure 12 Percent of projects achieving each credit with respect to the four certification levels

A general observation of figure 20 shows that the percent of projects achieving each credit is increasing with the increase in certification level, and in some credits, Platinum is achieved by a much bigger percentage. This translates the need for Platinum projects to achieve a larger batch of credits to guarantee certification.

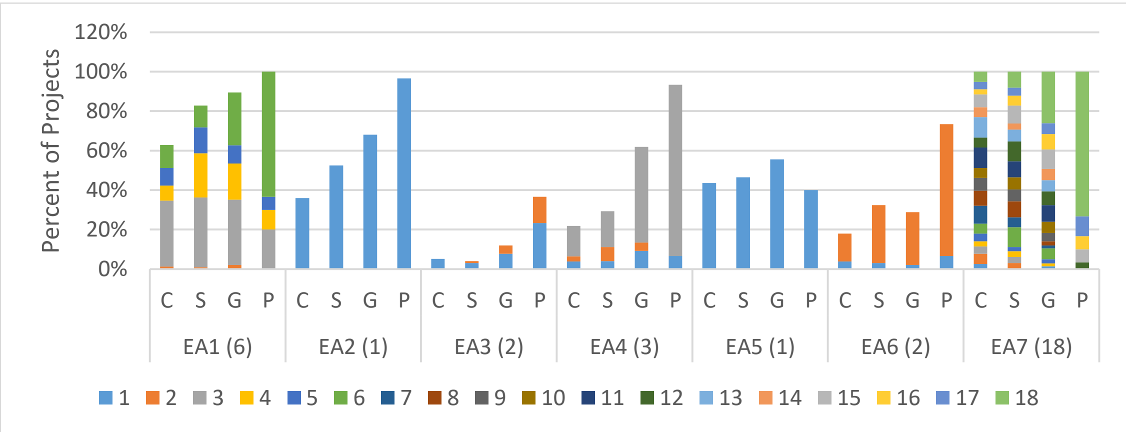
Further analysis was performed to visualize the percentage of projects achieving each number of points in each certification level. Figure 20**Error! Reference source not found.** shows the number of points achieved in the Sustainable Sites category. A general pattern of an increasing percentage of achieved projects with the increase in certification level is present. Notably, certified, Gold and Silver projects only seek 2 points for credit SS2 (Site development - protect or restore habitat), while Platinum projects achieved one point in some cases and 2 points in others. This might be due to the fact that some Platinum projects cannot disregard the credit altogether, hence they settle for achieving one point instead of two. The percentage of projects achieving one point is almost constant for credit SS5; however, the percentage of projects achieving two points increases with the increase in certification level.



Note: In parenthesis is the maximum number of points that can be achieved for that credit.

Figure 13 Percentage of projects achieving each number of points in the Sustainable Sites category

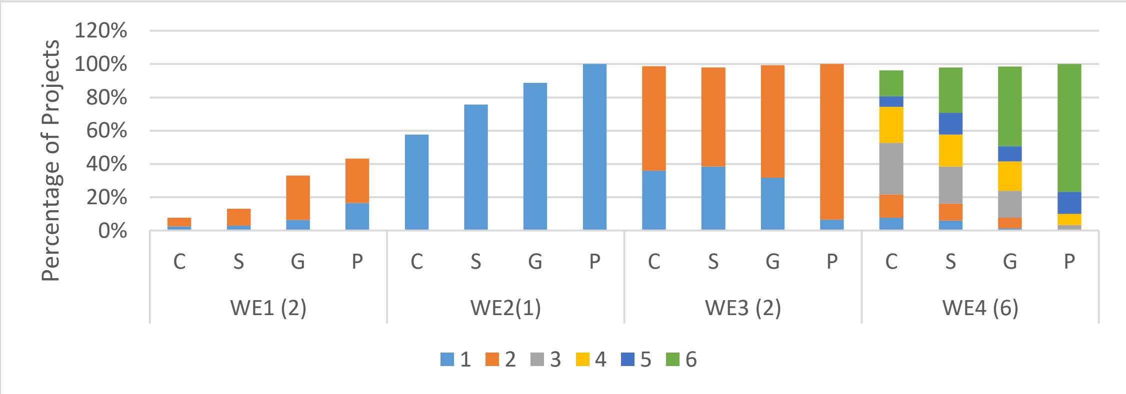
Figure 21 Shows the project point achievements in the Energy and Atmosphere category. For credit EA1 (Enhanced commissioning), the green band representing six points increases with the increase in certification level, and the percentage of projects achieving two points is very little across all categories and is zero for Platinum certified projects. The same observation applies to credit EA4 (Renewable Energy Production) where Platinum projects either achieve one or three points, while zero percent of projects achieve two points. According to the credit requirements, 1% of renewable energy produced enables the project to achieve one point, 5% grants two points and 10% grants three points. Apparently, project stakeholders prefer to invest all the way to 10% and get the three points or be fulfilled with only one point for one percent. Credit EA7 (Optimize Energy Performance) can achieve a maximum of 18 points. Certified projects are scattered across all number of points, while less projects achieve low number of points for higher certification levels, and the bands for high number of points expands gradually. More than 85% of Platinum certified projects aim to gain a full score of 18 points. This is not possible for lower certification levels due to the large investment required to reach this achievement.



Note: In parenthesis is the maximum number of points that can be achieved for that credit.

Figure 14 Percentage of projects achieving each number of points for Energy and Atmosphere category

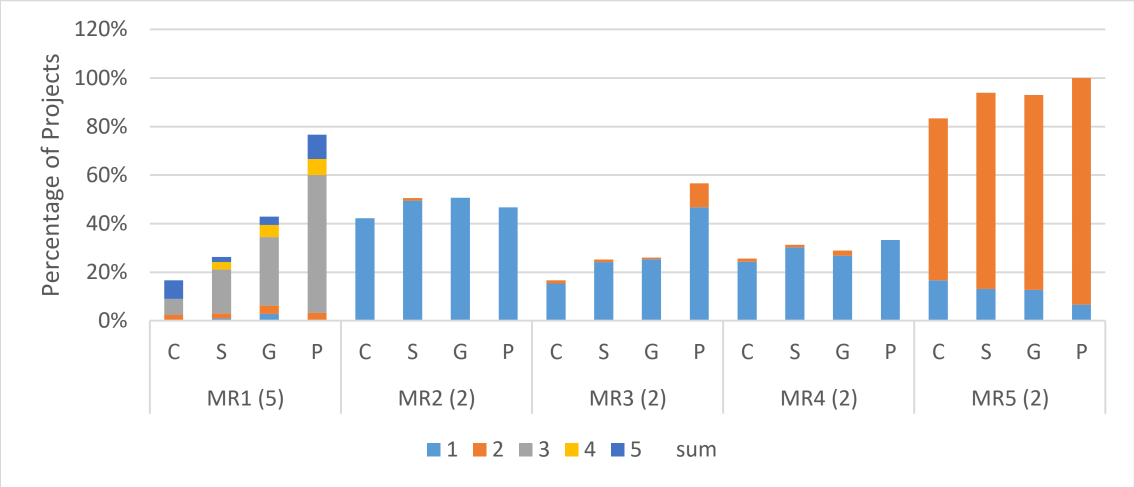
Figure 22 shows the percentage of projects achieving each number of points for the Water Efficiency category. Patterns are observable; projects achieve a higher number of points with the increase in certification level. This can be related to the nature of credit requirements of this category, where a larger percentage in improvement grants larger number of points.



Note: In parenthesis is the maximum number of points that can be achieved for that credit.

Figure 15 Percentage of projects achieving each number of points for Water Efficiency category

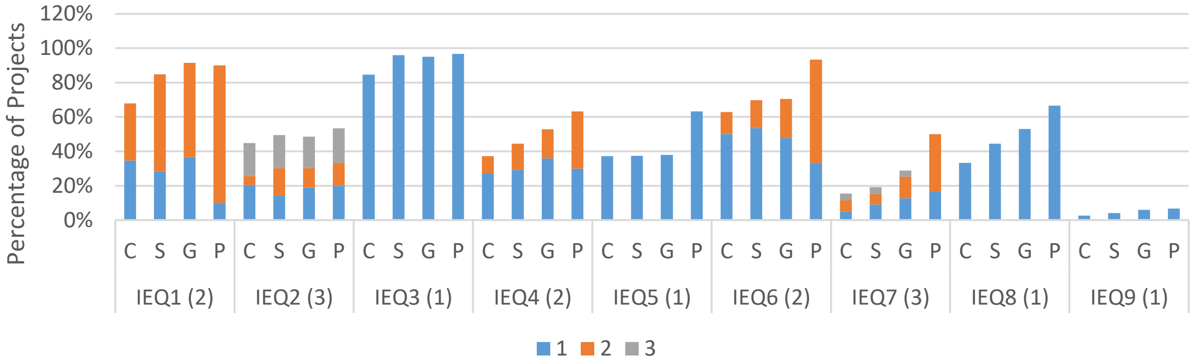
Figure 23 shows the percentage of projects achieving each number of points for the Material and Resources category. Similar observations as previous categories apply for credits MR1, MR3, and MR5. Credits MR2 and MR4 witness very low percentages for projects achieving two points for all certification levels. This might be related to the hard or costly process of procuring materials conforming to environmental product declarations or material ingredients conditions.



Note: In parenthesis is the maximum number of points that can be achieved for that credit.

Figure 16 Percentage of projects achieving each number of points for Material and Resources Category

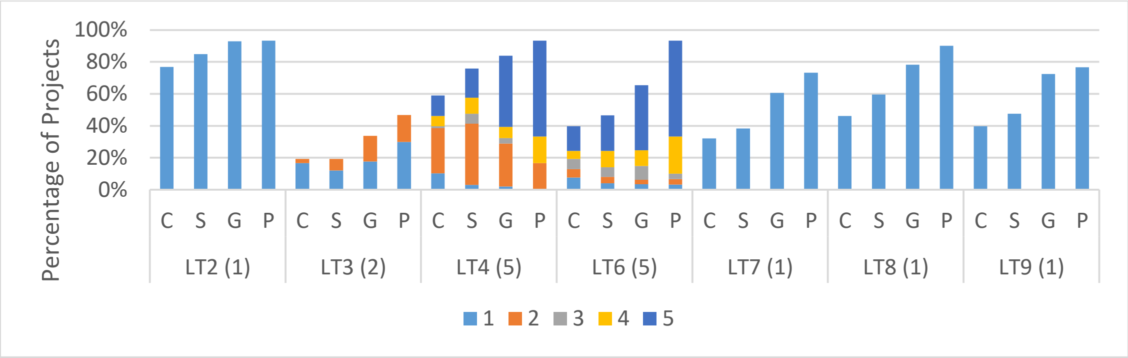
Figure 24 shows the percentage of projects achieving each number of points for the Interior Environmental Quality category. Similar observations apply for previous categories except for credits IEQ1, IEQ3, and IEQ5. The first credit (Enhanced Indoor Air Quality Strategies) does not have a consistent pattern, this might be due to the condition set by the credit of either complying with three strategies for one point or six strategies for two points. Several projects might be aiming for six points and end up getting only one point in case any strategy fails. IEQ5 (Thermal Comfort) have interesting results since only Platinum certified projects witness an increase in the percentage of projects achieving it. This signifies the fact that projects are more in need to achieve a bigger batch of credits to achieve the number of points required.



Note: In parenthesis is the maximum number of points that can be achieved for that credit.

Figure 17 Percentage of projects achieving each number of points for Indoor Environmental Quality category

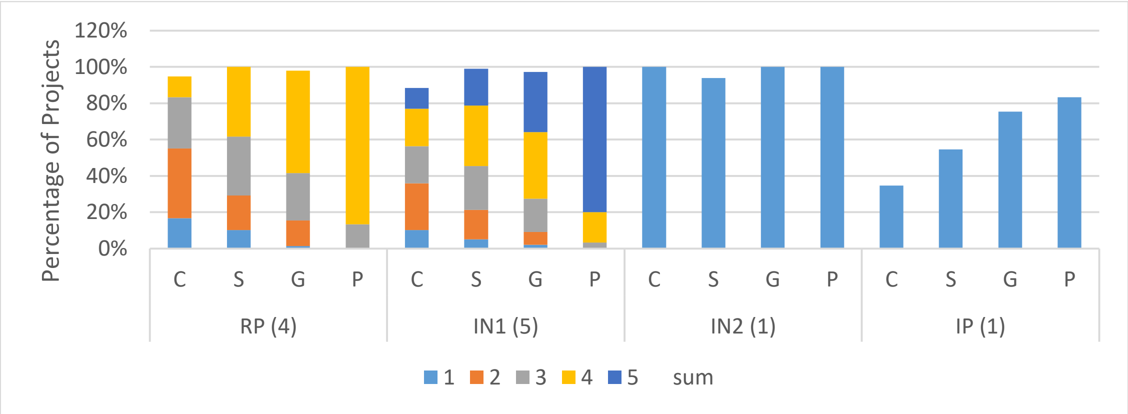
Figure 25 Shows the percentage of projects achieving each number of points for the Location and Transportation category. Credits conform to the pattern of increasing percentage of projects achieving a higher number of points as certification level increases.



Note: In parenthesis is the maximum number of points that can be achieved for that credit.

Figure 18 Percentage of projects achieving each number of points for Location and Transportation category

Figure 26 is a combination of the sum of the Regional Priority credits, Innovation credits and Integrative Process credit. Generally, the same trend applies to all.



Note: In parenthesis is the maximum number of points that can be achieved for that credit.

Figure 19 Percentage of projects achieving each number of points for Regional Priority, Innovation and Integrative Process credits

5.4 Theoretical Background on Data Analysis

The data analysis performed utilized tools provided by R software to determine the credits that show statistically significant difference in number of points achieved across the four certification levels.

5.4.1 R Software

R software provides an environment for data manipulation, statistical computing and graphical display [89] . It is favored since it has the ability for effective data handling, provides sufficient storage facility, offers a vast integrated pool of intermediate tools used in data analysis, and provides a well-developed simple and effective programming language called “S”. The software has developed rapidly with time and has been extending with large collections of packages [89].

5.4.2 Classification and Regression Trees (CART)

Classification or regressions trees are algorithms used in machine learning for predictive modeling [90]. The first algorithm was published in 1963 by Morgan and Sonquist by developing the Automatic Interaction Detection Program (AID) [91], [92]. Several advancements emerged in the subsequent years, and in 1984 Breiman et al published the Classification and Regression Tree algorithms (CART). CART differs from AID in the pruning and estimation procedure followed; it works on growing a large tree then pruning it to the size that maintains the lowest cross-validation estimate of error [91].

The goal behind regression tree implementation is to let the model understand the dataset and be able to perform predictions based on the knowledge it has gained from data analysis. The data under analysis must include a column for the outcome that needs to be modeled. It should also include predictor columns that enable the model to shape its understanding of the data and consequently be able to make predictions accordingly. In this study, the outcome is the certification level, and predictors are the credits required to achieve LEED certification. The classification or regression model is developed as a tree structure, where the dataset is partitioned into smaller subgroups in a way that incrementally develops the tree [93].

The resulting tree is comprised of decision nodes based on the predictors, and leaf nodes representing a decision concerning the outcome. In this case, the prediction is which level of certification the project is most likely to achieve [93]. On each node, splits are labeled by the splitting criterion causing the split which, in this study, is the number of points achieved by each credit [94]. Figure 28 shows a plot of the regression tree for the projects achieving Platinum and Gold levels. The aim is to classify the credits that have the number of points achieved by higher certification levels significantly different than lower ones.

Regression trees are programmed to split the data into a right branch and a left branch. The right branch includes the data points that do not comply with the stated condition, hence having an opposite value to it, while the left branch includes the data that comply to the condition.

Figure 20 Classification tree for Platinum and Gold Projects

In the regression tree plot of the LEED credits present in figure 27, the total number of projects achieving Gold and Platinum certification is 172 where 142 projects achieved Gold certification and 30 projects achieved Platinum certification. The first split shows that 25 out of 30 Platinum projects and 45 out of 142 gold projects scored higher than 16.5 points in the energy and atmosphere credit number 7 (EA7). On the other side, most of the Gold projects, 97 out of 142, and only 9 out of the 30 Platinum projects achieved less than 16.5 points in EA7. This signifies that it is highly preferable to get more than 16.5 points in EA7 to achieve Platinum certification.

To code regression trees in R, the package rpart is required. Then, three steps are to be followed[95]:

Table 14 Steps followed and functions used in regression tree analysis

Step		Function
1	Grow Tree	rpart (outcome~predictor1+predictor2+ etc., data=, method=, control=)
2	Examine the Results	plot(fit): to plot the cross-validation error text(fit): add text to the plot summary(fit): to view detailed results printcp(fit): to view values to complexity parameters plotcp(fit): to plot cross-validation results varImp(fit): to determine the importance of the listed variables
3	Prune the tree	it$cptable[which.min(fit$cptable[,"xerror"]),"CP"]: to determine lowest cp prune(fit, cp=): to prune the tree to size with the lowest cp.

5.4.3 Random Forest

Introduced by Breiman in 2001, random forests aim to improve the predictive accuracy of regression trees by generating a very large number of trees, a forest, and aggregating their predictions [94]. The random forest works by taking random combinations of predictors in each run, then combining these randomized trees and aggregating the resulting predictions by averaging them [94].

To implement random forests in R, the package randomForest is required and the following steps must be followed.

Table 15 Steps followed and functions used in random forest analysis

	Step	Function
1	Grow the Forest	randomForest (outcome~predictor1+predictor2+predictor3+etc., data=)
2	Examine the Results	Print(fit): to view results that include OOB estimate of error rate and the confusion matrix

5.5 Statistical Analysis Results

The following sub-section elaborates the statistical analysis results performed on LEED-credit data. The model aims to model the 4 LEED certification levels based on the credits achieved. This allows to classify the credits that have significant difference in achievement across higher certification levels than lower ones. Consequently, this group of credits becomes a condition to achieve a high certification level, and failing to achieve these credits could lead to failing to realize the desired certification.

Two statistical analysis methods are performed. First regression tree analysis is performed across all combinations of the four certification levels, it shows the number of points required to be achieved in each conditional credit that makes a higher certification level significantly different than the one below it. The second is random forest analysis; it provides the important credits to be achieved across different certification levels.

5.5.1 Regression Tree Results

Regression tree analysis is performed for each two consecutive certification levels for each category to determine the significant credits to be achieved across these two certification levels.

Second, analysis is performed across all combinations of certification levels: Platinum and Gold, Platinum and Silver, Platinum and Certified, Gold and Silver, Gold and Certified, and Silver and Certified. For this analysis, predictors include all credits, and the outcome is the certification level.

5.5.1.1 Regression Tree Analysis for each Category

Regression tree analysis was performed across projects from each two consecutive certification levels for each category at a time. The aim behind this is to understand the credits to concentrate on for each category. The tables listed in this subsection summarize the results given by regression trees between Gold and Platinum projects, Silver and Gold projects, and silver and certified projects. For each category, the first row is set to track the tree splits. Appendices A, B and C include regression tree plots that are summarized in tables 15 to 17. The second row states the condition at that split, which is the number of points achieved by that credit, and the third row is to define the ratio of the projects complying to this condition.

Table 16 Credit conditions for Platinum and Gold projects across categories

Sustainable sites	Split	1	2	3
	Credit Condition	**SS4>2.5**	**SS5>1.5**	**SS3>0.5**
	Ratio	24/30	22/24	20/22
Energy and Atmosphere	Split	1	2	3
	Credit Condition	**EA7>16.5**	**EA6>0.5**	**EA1>5.5**
	Ratio	25/30	18/25	11/18
Indoor Environmental Quality	Split	1	2	
	Credit Condition	**IEQ6>1.5**	**IEQ>0.5**	
	Ratio	18/30	9/18	
Location and Transportation	Split	1	2	3
	Credit Condition	**LT5>3.5**	**LT7>0.5**	**LT5>=4.5**
	Ratio	25/30	23/25	16/23
Water Efficiency	Split	1	2	
	Credit Condition	**WE4>4.5**	**WE3>1.5**	
	Ratio	27/30	25/27	
Innovation and Regional Priority	Split	1		
	Credit Condition	**IN1>4.5**		
	Ratio	24/30		
Material and Resources	Split	1	2	3
	Credit Condition	**MR1>2.5**	**MR3>0.5**	**MR4>0.5**
	Ratio	22/30	12/22	8/12

Note: splits are sequential; they track the number of projects complying to each condition the splits of the branch. The ratio indicates the number of complying projects out of the number of projects in that split.

The first item in the first row signifies that at the first split, 24 out of the 30 platinum projects had a sustainable sites' score higher than 2.5. Hence, most projects scored 3 points, which is the maximum number of points for this credit. The next column, at the second split, 22 out of the 24 projects branched in the first split, have a sustainable sites' score higher than 1.5. Hence, most projects achieved 2 points, which is the maximum score for that credit as well. At the third split, 20 out of the 22 projects classified in this branch had a score higher than 0.5 for SS3, hence scoring the maximum number of points for that credit which is only 1 point. The same elaboration applies to the remaining categories.

Table 17 Credit conditions for Gold and Silver projects across categories

Sustainable Sites	Split	1	2	3
	Credit Condition	SS2<1	SS4>0.5	SS1>0.5
	Ratio	90/142	46/90	38/46
Energy and Atmosphere	Split	1		2
	Credit Condition	**EA4>0.5**		
	Ratio	88/142		
Indoor Environmental Quality	Split	1	2	3
	Credit Condition	IEQ7<0.5	IEQ1>0.5	IEQ8>0.5
	Ratio	101/142	94/101	41/94-
Location and Transportation	Split	1	2	3
	Credit Condition	LT4<4.5	LT8>0.5	LT5>4.5
	Ratio	63/142	44/63	36/44
Water Efficiency	Split	1	2	3
	Credit Condition	WE1>0.5	WE4>1.5	WE2>0.5
	Ratio	47/142	46/47	44/46
Innovation and Regional Priority	Split	1	2	
	Credit Condition	**IN2>0.5**	**IN1>3.5**	
	Ratio	142/142	99/142	
Material and Resources	Split	1	2	
	Credit Condition	MR1>0.5	MR1<4.5	
	Ratio	61/142	56/61	

Note: splits are sequential; they track the number of projects complying to each condition the splits of the branch. The ratio indicates the number of complying projects out of the number of projects in that split.

Table 16 shows the credit conditions for projects achieving Gold and Silver certifications. This group of projects did not have distinct categorizations as the previous table. In some categories, such as sustainable sites, location and transportation, water efficiency, indoor environmental quality and material and resources, the first split either has a condition for a higher limit rather than lower limit, or the split does not have many projects complying to it. That said, only conditions marked in bold will be taken into consideration in further analyses.

Table 18 Credit conditions for Silver and Certified projects across categories

Sustainable Sites	Split	1	2	3
	Credit Condition	SS4<2.5	SS3>0.5	SS4>1
	Ratio	68/99	36/68	35/36
Energy and Atmosphere	Split	1	2	3
	Credit Condition	**EA1>1**	**EA6<0.5**	**EA2>0.5**
	Ratio	82/99	54/82	35/54
Indoor Environmental Quality	Split	1	2	
	Credit Condition	**IEQ1>1.5**	**IEQ3>0.5**	
	Ratio	56/99	53/56	
Location and Transportation	Split	1	2	3
	Credit Condition	**LT4>1.5**	**LT3<1.5**	**LT2>0.5**
	Ratio	72/99	65/72	59/65
Water efficiency	Split	1	2	3
	Credit Condition	WE4<4.5	WE3>0.5	WE1<0.5
	Ratio	59/99	57/59	50/57
Innovation and Regional Priority	Split	1		
	Credit Condition	**IN>2.5**		
	Ratio	77/99		
Material and Resources	Split	1	2	3
	Credit Condition	**MR5>0.5**	**MR1<4.5**	**MR1<2.5**
	Ratio	93/99	91/93	71/91

Note: splits are sequential; they track the number of projects complying to each condition for splits of the branch. The ratio indicates the number of complying projects out of the number of projects in that split.

Table 17 shows the credit conditions for projects achieving Silver and Certified certifications. Sustainable sites and water efficiency categories will not be considered in further analysis, since the split condition is an upper limit rather than a lower limit that the projects must exceed in order to achieve certification.

5.5.1.2 Regression Tree Analysis across certification levels

This subsection elaborates the results of regression tree analysis, including all credits, performed across all combinations of certification levels. The aim behind this analysis is to be able to relate data analysis results to the theoretical model for green liquidated damages proposed in chapter 3. Appendix D shows the plots of regression tree analysis results of this subsection.

5.5.1.2.1 Platinum Projects compared to Gold, Silver and Certified projects

Table 18 reflects the results of regression tree analysis performed on platinum certified projects as compared with Gold projects, Silver Projects and Certified projects consequently.

Table 19 Regression tree analysis results of Platinum certified projects in comparison to other certifications

	Platinum to Gold		**Platinum to Silver**		**Platinum to Certified**	
Split	1	2	1	2	1	2
Credit Condition	**EA7>16.5**	**LT5>3.5**	**EA7>16.5**	**LT5>0.5**	**EA7>15.5**	**WE4>4.5**
Ratio	25/30	20/25	25/30	23/25	27/30	24/27

Table 19 compiles three lists including credit importance factors for the three regression trees summarized in table 18. Credits highlighted in bold represent the credits that constitute a split in the regression trees.

Table 20 Variable importance for regression trees classifying credits of Platinum projects and other certifications

Platinum to Gold			Platinum to Silver			Platinum to Certified	
Credit	**Importance**		**Credit**	**Importance**		**Credit**	**Importance**
LT5	**13.256**		**EA7**	**20.373**		**EA7**	**24.083**
LT4	8.153		**LT5**	**10.914**		EA4	13.379
EA7	**7.882**		EA4	9.911		SS4	13.196
EA4	3.04		IN1	7.556		**WE4**	**9**
EA1	2.551		EA2	6.716		IN1	7.358
WE1	2.125		LT4	5.877		MR1	7.358
SS6	1.7		WE4	4.198		RP	7.358
SS4	1.275		EA3	3.854		LT4	6
IEQ7	0.788		SS4	3.358		LT5	6
LT6	0.45		IEQ7	3.303		IP	5.25

Note: credits in bold represent the credits observed in the results of random forest analysis.

It is important to note that the credits causing the splits in regression trees are not necessarily the top credits in the variable importance list. This is because surrogates, which act as substitute splitters for every node in the tree in the backstage process to reach the actual splitters, are also included in importance calculations. Therefore, a variable might show a high importance factor even though it never showed a split [96]. This applies to all trees listed in this subsection.

5.5.1.2.2 Gold projects compared to Silver and Certified projects

Table 20 views the results of regression tree analysis performed on Gold certified projects as compared with Silver projects and Certified projects consequently. While table 21 compiles the lists including credit importance factors for the two regression trees summarized in table 20.

Table 21 Regression tree analysis results of Gold certified projects in comparison to Silver and Certified projects

	Gold to Silver		Gold to Certified		
Split	1	2	1	2	3
Credit Condition	**EA4>0.5**	**LT4>4.5**	**RP>2.5**	**IN1>2.5**	**IP>0.5**
Ratio	70/99	57/70	118/142	103/118	86/103

Table 22 Variable importance for regression trees classifying credits of Gold projects compared to Silver and Certified Projects

Gold to Silver			Gold to Certified	
Credit	**Importance**		**Credit**	**Importance**
EA4	**12.072**		**RP**	**23.749**
LT4	**9.874**		**EA4**	**15.354**
LT5	5.161		**IN1**	**12.58**
EA7	4.436		**LT4**	**7.557**
IEQ1	1.96		WE4	7.545
IEQ2	1.857		LT5	4.534
WE4	1.359		LT6	4.03
MR2	1.341		MR1	4.03
MR1	0.897		EA7	3.969
LT3	0.224		EA2	3.235
			SS4	2.983
			IP	**2.971**

Note: credits in bold represent the credits observed in the results of in random forest analysis.

5.5.1.2.3 Silver projects compared to Certified projects

Table 22 views the results of regression tree analysis performed on Silver certified projects as compared with Certified projects. While table 23 lists credit importance factors for the regression tree results summarized in table 22.

Table 23 Regression tree analysis results of Silver certified projects in comparison to Certified projects

Silver to Certified		
Split	1	2
Credit Condition	**RP>2.5**	**EA1>1**
Ratio	70/99	57/70

Table 24 Variable importance for regression trees classifying credits of Silver projects compared to Certified Projects

Importance SC	
RP	**8.014**
EA6	6.095
EA1	**6.007**
IN1	3.555
WE4	1.495
IEQ4	1.185
IEQ3	1.162
EA4	0.948
IEQ1	0.948
MR5	0.948

Note: credits in bold represent the credits observed in the results of in random forest analysis.

5.5.2 *Random Forest Analysis Results*

Regression tree analysis was performed to get more accurate results, which indicate the important credits that differ in achievement between certification levels. First, random forest analysis was performed on all projects achieving all certification levels. The aim behind this forest is to get a holistic view for the important indicators affecting certification level achievement. Then, random forests were performed across Platinum and Gold projects, Gold and Silver projects, and finally Silver and Certified projects. Table 24 compiles the results of these random forests.

Table 25 Random forest analysis results

All Credits All Levels		Platinum &Gold		Gold & Silver		Silver & Certified	
Credit	**Imp.**	**Credit**	**Imp**	**Credit**	**Imp**	**Credit**	**Imp**
EA7	7.5496	EA7	3.496	EA7	6.1039	RP	4
EA4	7.0932	IN1	1.9379	EA4	5.0654	IN1	2.88
IN1	6.728	EA6	1.86	LT4	4.251	EA7	2.765
RP	6.679	EA1	1.7689	WE4	2.76	LT4	2.363
LT4	5.26	LT5	1.698	LT5	2.732	EA1	2.215
EA1	4.6	EA4	1.6	IN1	2.357	WE4	2.105
MR1	4.519	SS4	1.5535	EA1	2.28	IEQ1	2.053
WE4	4.354	MR3	1.377	LT8	2.262	SS4	1.707
LT5	4.017	IEQ6	1.3	RP	2.04	IP	1.4
IP	3.542	MR1	1.2675	IP	1.91	SS3	1.233
SS4	3.11	LT4	1.06	LT6	1.675	EA6	1.2322

5.6 Discussion of statistical analysis

Statistical analysis was performed using two analysis methods: regression tree analysis and random forest analysis. The former was applied on credits in two forms:

- The first performed comparison across all the credits at once across the four certification levels and between each two certification levels. This allows to determine the overall important credits that project stakeholders must be attentive to upon planning for certification. Furthermore, these credits are the ones to be careful with upon drafting the liquidated damages contract since they are determinate in achieving the desired certification levels.
- The second analysis round performed comparison of credit achievements across each category. The aim behind this is to highlight the most important credits upon zooming in to each category at a time.

Further on, random forest analysis was performed to obtain a higher accuracy for determining the important credits. This way, one could benefit from regression tree analysis for credit conditions and from random forest analysis for a more accurate credit importance.

Table 25 offers a summary for all credit conditions across categories for three comparisons of consecutive certification levels, in addition to random forest results.

Table 26 Compilation of statistical analysis results

Gold & Platinum			**Silver & Gold**			**Certified & Silver**		
Regression tree analysis on all credits								
EA7≥17			**EA4≥1**			**RP≥3**		
LT5=4			**LT4=5**			**EA1=2**		
Regression Tree Analysis on Each category*								
1st split	2nd split	3rd split	1st split	2nd split	3rd split	1st split	2nd split	3rd split
SS4=3	SS5=2	SS3=1						
EA7≥17	EA6≥1	EA1=6	**EA4>0.5**			**EA1≥2**		
IEQ6=2	IEQ≥1					IEQ1=2	IEQ3=1	
LT5=4	LT7=1	LT5=5				LT4≥2		
WE4≥5	WE3=2							
INN1=5			INN2=1	IN1≥4		INN1≥3		
MR1≥3	MR3≥1	MR4≥1				MR5≥1		
Random Forest Analysis								
Credit	**Importance**		**Credit**	**Importance**		**Credit**	**Importance**	
EA7	3.496		EA7	6.1039		**RP**	4	
INN1	1.9379		**EA4**	5.0654		INN1	2.88	
EA6	1.86		**LT4**	4.251		EA7	2.765	
EA1	1.7689		WE4	2.76		LT4	2.363	
LT5	1.698		LT5	2.732		**EA1**	2.215	

*Note: splits are sequential. Equal signs are put when the threshold is the maximum number of points that can be achieved for that credit.

According to the statistical analysis results, Platinum projects significantly differ from Gold projects in that they achieve 17 or above points in credit EA7 (optimize energy performance), and a full score of four points for credit LT5 (access to quality transit). These credits are listed in the top five important credits resulting from random forest analysis. Moreover, upon zooming in and focusing on each category at a time, credit SS4 (rainwater management) must achieve a full score of 3 points, credit IEQ6 (interior lighting) must achieve a full score of 2 points, credit WE4 (indoor water use reduction) must achieve a score of 5 or 6 points, the first innovation credit must achieve a full score of 5 points, and MR1 (building life-cycle impact reduction) must achieve a full score of five points. These credits are the ones that showed up in the analysis since, upon comparing the number of points achieved by credits of each category, they significantly achieved a full score. These scores are substantial since the demand for a collection of a large number of points for Platinum certification obliges the project to achieve full score with respect to certain credits, which is not the case for other certification levels.

Upon comparing Gold and Silver projects, credit EA4 (Renewable energy production) is required to achieve its maximum of 1 point, and credit LT4 (surrounding density and diverse uses) is required to achieve its maximum of 5 points. When zooming to each category at a time, the analysis does not show distinct conditions for credits. Other than the EA4 condition, innovation category requires full point achievements in both credits; INN1 (innovation) and INN2 (LEED accredited professional). This shows that the innovation category is important to achieve for Gold projects as compared to Silver projects, unlike other categories where no distinct unified pattern takes place. Random forest analysis showed EA7, EA4 and LT4 as the top three important factors, but did not list innovation credits in the top ten important ones. Therefore, even though they do show a clear condition for achievement, innovation credits are not amongst the most important credits for stakeholders to focus on.

The comparison between Certified and Silver projects highlights a different batch of credits to emphasize. The sum of points achieved by regional priority credits must achieve 3 or the maximum of 4 points, and credit EA1 (Enhanced commissioning), whose maximum is 6 points, must achieve more than one point only. The difference here is that these two credits might not be critical to achieve in the case of Certified projects but become important when it comes to Silver projects. Moreover, the sum of RP credits is ranked first in the random forest importance list, and EA1 is ranked fifth. Upon zooming to category-by-category analysis, credit IEQ1 (enhanced IEQ strategies) must achieve its maximum of 2 points, credit LT4 (surrounding density and diverse uses) has to achieve 2 points or above, credit INN 1 has to achieve 3 or more points, and credit MR5 (construction and demolition waste management) has to achieve its maximum of 2 points.

So far, this analysis has been helpful in informing us about the number of points that must be achieved by credits to realize higher certification levels. These credits become the ones to focus on when intending to target a certain certification level, and the ones to be careful to achieve.

CHAPTER 6

TOWARDS FORMULATING A GLD RECOVERY MECHANISM

6.1 Preamble

The aim behind this research is to formulate a recovery mechanism for Green Liquidated Damages, defined previously as the compensation for owner's loss upon certification failure. From the conditions and guidelines of LD recovery deduced in chapter 3, the composition, rate and recovery mechanism of GLD are highlighted as concepts to be explored in this research. This chapter relates the findings of chapters 4 and 5 to these three concepts and concludes with a framework for the proposed recovery mechanism.

6.2 Determining rate of levying GLD

One of the key aspects is the rate upon which GLD is levied. In the case of delay liquidated damages, a daily LD rate is determined, and the amount keeps on aggregating as days pass up until the ceiling is reached. The theoretical model, proposed in chapter 3, introduces a new concept for levying damages that is not based on aggregation of days or performance records. The theoretical model proposes that the rate of levying damages is determined by the loss in certification level, and that each loss has its unique value. Logically, F (P, S) is larger than F (P, G), but it is not the value of the latter added by a certain amount. This subsection aims to verify this model using the obtained statistical analysis results.

Statistical analysis was performed on all combinations of certification levels to be able to determine the conditions for all scenarios representing the falls of a project desiring a certain certification level and ending up in a lower one. Platinum certified projects were compared to projects from all other certification levels, since it is the highest certification that could be achieved. That said, analysis was performed to understand the difference in credit achievements for projects seeking Platinum certification and ending up in Gold, Silver or Certified. Gold projects were compared to projects with lower certifications, namely Silver and Certified projects, while Silver projects were compared to Certified projects only.

The comparison of the credits achieved across two certification levels represents the extra efforts performed by the higher certification level that enabled it to achieve the higher record. Consequently, this effort becomes the condition to achieve that higher certification level. Failing to maintain it could result in failing to achieve the desired certification. That said, thresholds provided by statistical analysis become the factors most probably to be lost upon certification failure. The results in relation to the theoretical model are presented in figure 21.

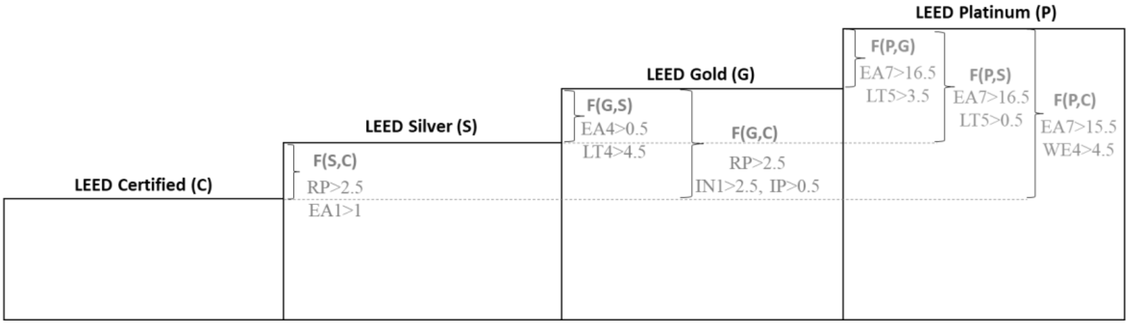


Figure 21 Statistical analysis results with respect to the theoretical model

A project losing the desired Platinum certification could end up in Gold, Silver, or Certified. These losses are represented in the model by the functions F (P, G), F (P, S), and F (P, C) consecutively. The conditions listed in figure 21 indicate that the fall from Platinum to Gold F (P, G) has the condition of EA7>16.5 and LT5>3.5, and the fall from Gold to Silver F (G, S) has the condition EA4>0.5 and LT4>4.5. On the other hand, the conditions governing the fall from Platinum to Silver F (P, S) are EA7>16.5 and LT5>0.5. These conditions show that the fall spanning from Platinum to Silver is not equal to the partial falls of Platinum to Gold and Gold to Silver. Therefore, the following applies:

$$F\ (P, S) \neq F\ (P, G) + F\ (G, S)$$

Furthermore, the fall spanning from Platinum to Certified F (P, C) has the condition of EA7>15.5 and WE4>4.5. The condition of the partial fall F (P, G) is EA7>16.5 and LT5>3.5, while the fall from Gold to Silver F (G, S) is EA4>0.5 and LT4>4.5, and of F (S, C) is RP>2.5 and EA>1. The conditions of these partial falls do not sum to be equal to the condition of the fall spanning from Platinum to Certified.

Therefore, the following equation is verified:

$$F\ (P, C) \neq F\ (P, S) + F\ (S, C)$$

Similarly, the conditions governing the fall from Gold to Certified F (G, C), RP>2.5, IN1>2.5, and IP>0.5, are different from the sum of conditions of the partial falls constituting it; conditions of F (G, S) are EA4>0.5 and LT4>4.5, and conditions of F (S, C) are RP>2.5 and EA1>1. Therefore, the following equation is verified:

$$F\ (G, C) \neq F\ (G, S) + F\ (S, C)$$

It is important to note that the falls that have Platinum as the initially intended certification level always have a condition governing credit EA7; it remained larger than 16.5 points upon comparing it to Gold and Silver and decreased to larger than 15.5 points upon comparing it to Certified projects. This empathizes the importance of the initially intended certification level on the impact of the fall. In this case, credit EA7 (Optimize Energy Performance) requires investments regarding energy efficiency systems and materials. Therefore, an owner seeking Platinum certification must invest in these systems to maintain a score of 17 or 18 to get the desired certification. Upon certain failures, when the project lands in Gold, Silver, or Certified, the investment put into credit EA7 is still there but might not be implemented properly to fulfill the requirements and earn the required points. For this reason, when a project loses Platinum certification, credit EA7 must be a considered factor. Comparisons starting from other certification levels such as Gold and Silver do not have this credit as a condition, because the owner does not need such a high score as when the case is to achieve Platinum.

6.3 The components of GLD amount

The concept of green liquidated damages is introduced as a control mechanism to maintain the owner's green certification goals. One of the main guidelines in the assessment of a liquidated damages amount is to account for the extra costs incurred by the owner and the lost benefits that can no longer be claimed due to the breach. In the case of green building certification, the goal is to achieve a determined green certification level from a defined rating system. This research focuses on the LEED rating system.

Owners must be compensated for the extra investment put in case the project does not achieve the desired certification. In the literature previously discussed throughout this work, the extra costs incurred by the owner are distributed across soft costs and hard costs. Soft costs are made up of the cost of the design premium assigned by the designer, the cost associated to hiring a LEED consultant, the cost associated to energy modeling required to be performed to satisfy some credits, commissioning costs incurred to hire a commissioning team, documentation costs, and LEED registration costs. Hard costs are related to installations and green products which are incurred primarily to satisfy the conditions of LEED credits.

Lost benefits include financial benefits, operational benefits, and government incentives. The financial benefits are represented by a price or rent premium, an increased occupancy rate, and an increase in the asset value. Operational benefits include water and energy savings. These two benefits, except for the asset value, are concurrent. The increase in price, rent or occupancy rate is a result of enhanced features that include monetary savings from operational advantages. That being said, financial benefits are a consequence of operational advantages. Therefore, an owner must levy only one of the concurrent lost benefits. Upon GLD quantification, the owner must determine the net present value of these monetary benefits over a defined period, of which the financial viability of the project was based upon.

Furthermore, owners seek certification to benefit from governmental incentives that vary depending on the country or state that the project is located in. These incentives could take the form of direct monetary incentives or intangible incentives. The former includes waiver of permit fee, tax incentives, or others depending on the location of the project. The latter includes expedited permitting and review and density bonuses. Governments follow compliance strategies towards developers that benefit from incentives but do not achieve certification, and as previously mentioned, these strategies might include a penalty equal to the net present value of the owner's monetary benefit from the incentive. An owner seeking benefit from one of these incentives must incorporate the penalty amount to the GLD clause.

These components make up the essential factors for determining the green liquidated damages amount stipulated in the contract. Figure 22 incorporates the components for Green Liquidated Damages assessment.

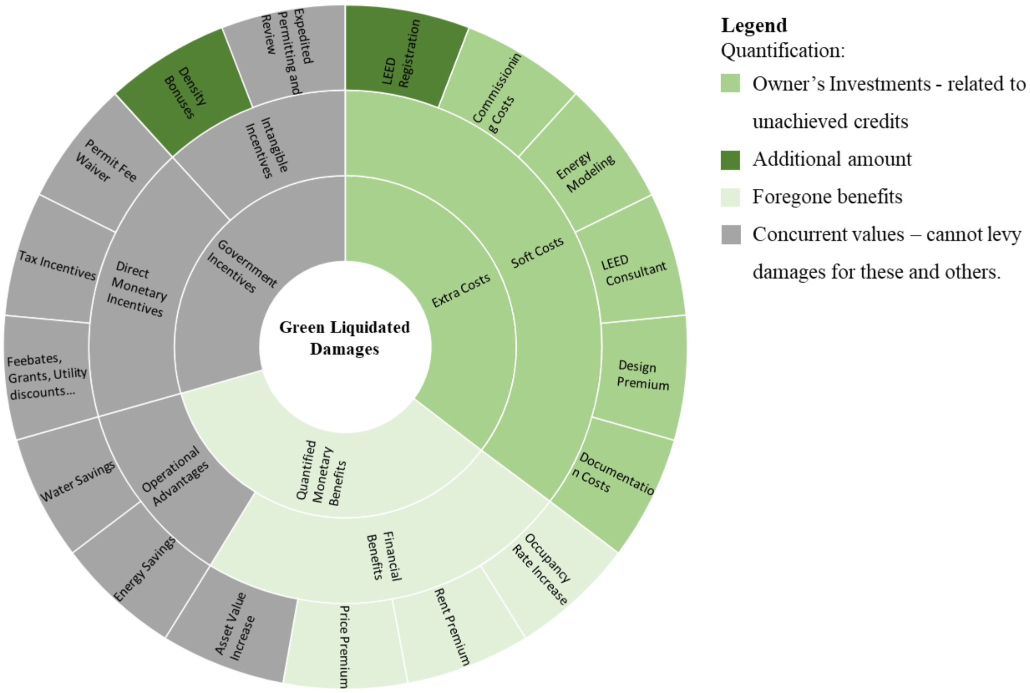


Figure 22 Components of Green Liquidated Damages Assessment

6.4 GLD recovery framework

As advised by the literature for liquidated damages assessment, the LD amount must reflect the extra costs paid due to breach and the lost benefits. The breach targeted by this research is certification failure; therefore, the owner must be compensated for the extra costs and lost benefits as a result of not achieving the desired certification.

The GLD clause must be constituted of three elements, each has a ceiling and a recovery mechanism. All must follow the theoretical model verified earlier in this chapter, except for the LEED registration fee that can be levied only in case of certification failure.

The first component compensates for the extra investment the owner paid in pursuit of certification. It includes hard costs and soft costs. The ceiling is dependent on the locality of the project. It is determined as a percentage of the contract amount of each party.

The recovery of liquidated damages must be a genuine estimate for probable loss. The extra investment put by the owner is to satisfy credits and collect points. A dollar amount must be associated to each point targeted by the plan and for each case of failure. Random forest analysis has determined the credits that are more important to achieve by higher certification levels. Therefore, the owner must set a higher dollar amount for the top important credits that are considered critical. Furthermore, regression tree analysis has provided thresholds for the number of points to be achieved by important credits. Each point above the threshold is more critical than the points beneath it.

Upon drafting the GLD clause, the owner must determine a dollar amount for each point across each credit depending on its importance and its value in comparison to the threshold. Upon certification failure, the owner compares the intended number of points and the actual achieved ones, and levies the predetermined amount associated to the lost points.

Table 27 lists credits in decreasing order of importance and the thresholds provided by regression tree analysis. From the values provided by table 27, an owner seeking Platinum certification must determine that in case he reaches Gold, the highest point rates are for credits EA7 and LT5 since they are the credits forming splits in regression tree analysis. The 18th and 17th point of credit EA7 must be higher than lower points, and the 4th point of credit LT5 must be higher than lower points achieved by credit LT5. If the owner is to end up at Silver, the highest point rates are still for credits EA7 and LT5, but in the case of credit LT5, all points of LT5 have equal rate since the threshold is to achieve larger than or equal to one point. The same applies to other combinations of certification levels, where the owner determines the rates for all the possible certification levels that he might end up at.

Table 27 Regression tree analysis and random forest analysis results comparing all combinations of certification levels

Thresholds provided by regression tree analysis results											
Tree PG		Tree PS		Tree PC		Tree GS		Tree GC		Tree SC	
EA7≥17		EA7≥17		EA7≥16		EA4=1		RP≥3, INN1≥3		RP≥3	
LT5=4		LT5≥1		WE4=5		LT4=5		IP=1		EA1≥2	
Credits sorted by decreasing importance by random forest analysis results*											
Forest PG		Forest PS		Forest PC		Forest GS		Forest GC		Forest SC	
Credit	Max. score	Credits	Max. score	Credits	Max. score	Credits	Max. score	Credits	Max. score	Credits	Max. scor e
EA7	18	EA7	18	EA7	18	EA7	18	RP	4	RP	4
INN1	5	EA4	1	SS4	3	EA4	1	INN1	5	INN1	5
EA6	2	INN1	5	RP	1	LT4	5	EA7	18	EA7	18
EA1	6	EA1	6	INN1	5	WE4	6	EA4	1	LT4	5
LT5	5	LT5	5	EA4	3	LT5	5	LT4	5	EA1	6
EA4	1	WE4	6	WE4	6	INN1	5	IP	1	WE4	6
SS4	3	MR1	5	MR1	5	EA1	6	EA1	6	IEQ1	2
MR3	2	SS4	3	LT5	5	LT8	1	LT5	5	SS4	3
IEQ6	2	LT4	5	EA2	1	RP	4	WE4	6	IP	1
MR1	5	EA3	2	LT4	5	IP	1	SS3	1	SS3	1
LT4	5	IEQ6	2	EA6	2	LT6	1	SS4	3	EA6	2

*Credits in grey are the ones with defined thresholds in regression tree analysis

In case an owner who lost Platinum certification intended to achieve 18 points for EA7 and ended up achieving 17 points, he must levy the dollar amount associated to this one point. However, in case he intended to achieve 16 points and he did obtain them, then the owner is not entitled to levy any amount.

The second component is an additional amount that takes account of the penalties the owner might be liable for in case of certification failure. Mainly, the penalty related to the bonus incentive that is equal to the monetary revenue from the extra area built as a grant for pursuing certification. The extra area that the owner is allowed to build is dependent on the certification level he is pursuing. Therefore, the owner must determine a value for each fall. The ceiling is the amount related to no certification at all. The owner should also indicate an amount to compensate for the LEED registration costs in case no certification is achieved.

The third component is related to the foregone benefits. The owner has a financial viability on his project based on the price or rent premium achieved as a benefit of certification failure. Depending on these premiums in the locality of the project, the owner must determine the monetary loss resulting from losing certification. Higher certification levels grant the owner higher price premiums; therefore, the owner must determine, for each certification level he lands at, the amount of lost benefits that he needs to recover for. Figure 23 summarizes the components of GLD, ceiling and recovery of each.

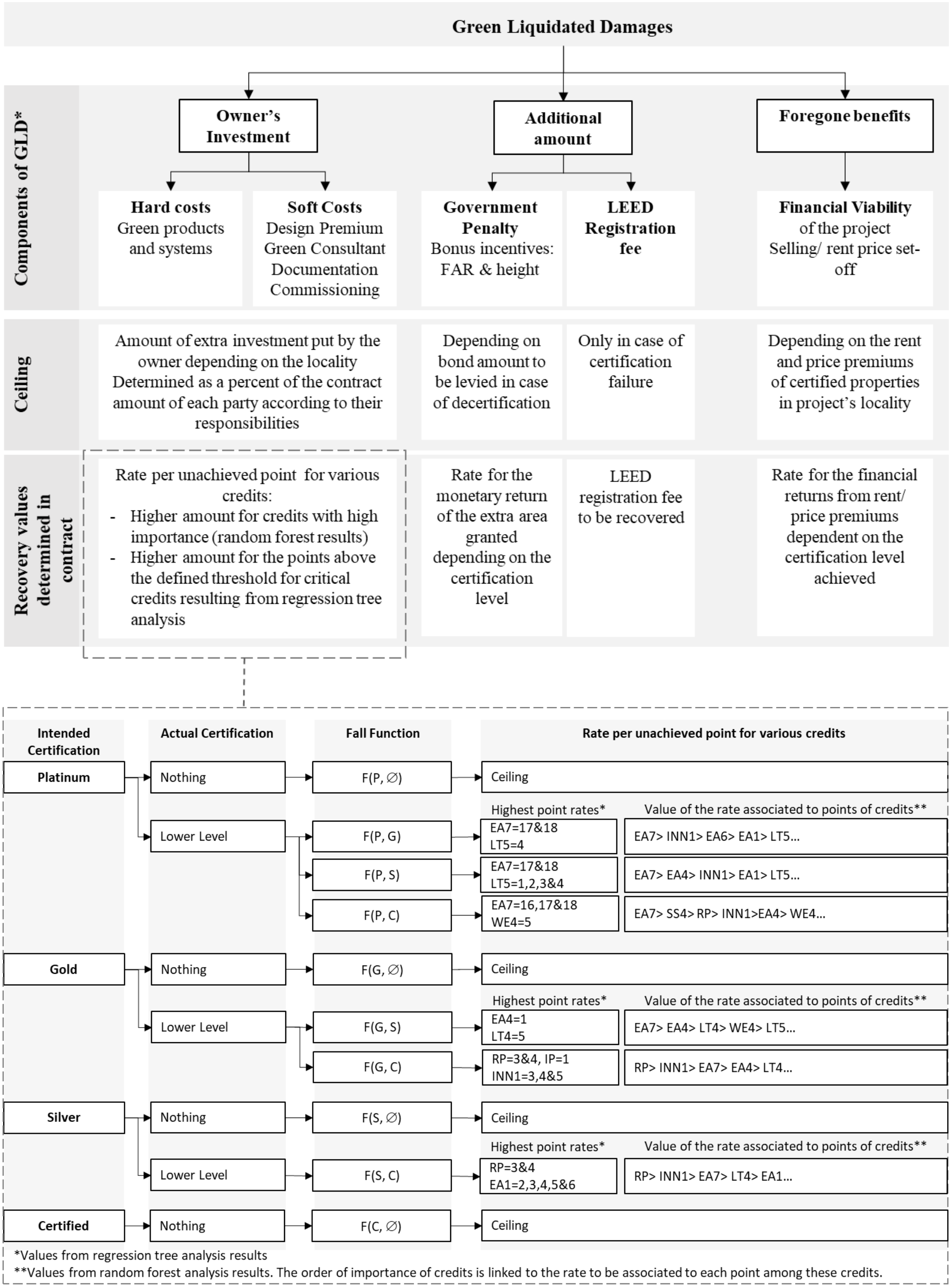


Figure 23 GLD framework

CHAPTER 7

CONCLUSIONS AND RECOMMENDATIONS

7.1 Summary of Findings and Contributions

The importance of green building research is increasing with the increase in urgency to hinder the impact of the building and construction sector on the environment. Consequently, green building research is a rising topic these days. Research topics tackle several aspects regarding the owner's perceived benefits, the costs, risks and barriers. Moreover, some research work discussed contractual advice to have more efficient green building contracts. However, no research work has offered strategies for compensation upon green building certification failure. This research work introduced the concept of Green Liquidated Damages as a step towards contractually preserving the owner's green goals when seeking green building certification, with the focus on USGBC's LEED rating system.

This objective was realized by compiling information from the literature regarding owner's perceived benefits and extra costs incurred to achieve LEED certification. This information was used to come up with the components for GLD amount. Moreover, a theoretical model was proposed regarding the rate for GLD recovery. Furthermore, to understand factors governing LEED certified buildings, data concerning the credits of projects achieving LEED certification was collected to determine the required critical credits for each certification level. Statistical analysis results were used to verify the theoretical model of LD recovery and determine the credits and points that must be associated with higher recovery rates. A framework combining the three components of GLD is proposed. It determines how the ceiling must be determined for each, and the recovery values to be stated in the contract.

7.2 Limitations

Several limitations are associated with this study. The first limitation corresponds to the lack of sufficient historical data regarding green building projects, which include information on green buildings that aimed for certification and lost it. Detailed information regarding case law is also absent. Such data would have enabled the determination of factors and parameters that lead to certification loss and unfolded the distribution of responsibilities across project parties.

Data regarding green building costs has lots of variables depending on project's type and region. This issue prevented the work from reaching defined cost values and associating them to green liquidated damages amounts. The same applies to monetary values associated to green building benefits. Reliable values concerning these two factors help in better quantification of damages resulting from green building certification failure.

7.3 Recommendations for Future Research

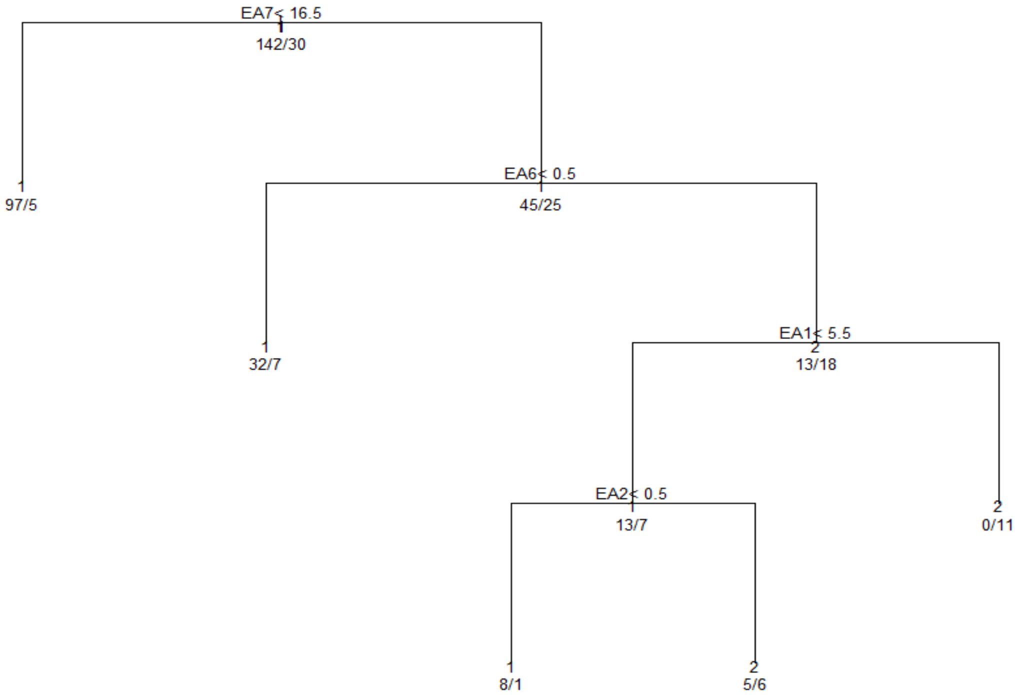
Future work may consist of acquiring a large data set of case studies discussing projects that failed certifications. Upon knowing areas of default, contractual tools of control set by owners can be better directed to guarantee goal achievement. In addition, case studies provide a space for in depth investigations concerning the importance of the role of each stakeholder associated to LEED certification achievement. Furthermore, research can be performed across various rating systems and upon considering projects based on a specific country or specific project type. Moreover, surveys can be sent to practitioners in green building projects or lawyers working in the green building industry to collect general guidelines for better formulation of Green Liquidated Damages clauses.

In later stages, when Green Liquidated Damages clauses are common in green building practice, research can be performed to track the effectiveness of these clauses. Future research can also discover whether these clauses achieve better compliance by contractors or better maintain owner's interests.

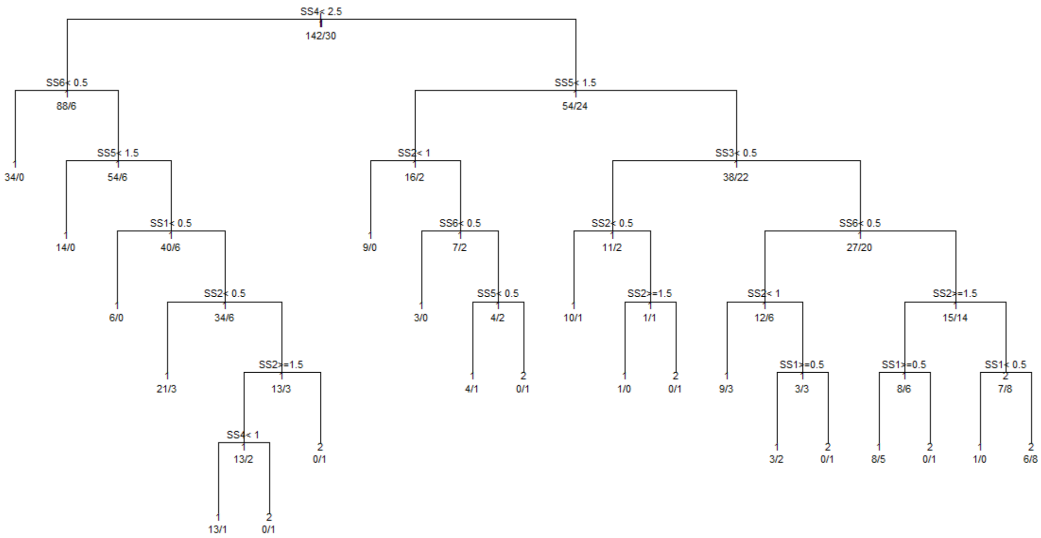
APPENDIX A

REGRESSION TREE PLOTS FOR PLATINUM AND GOLD PROJECTS ACROSS EACH CATEGORY

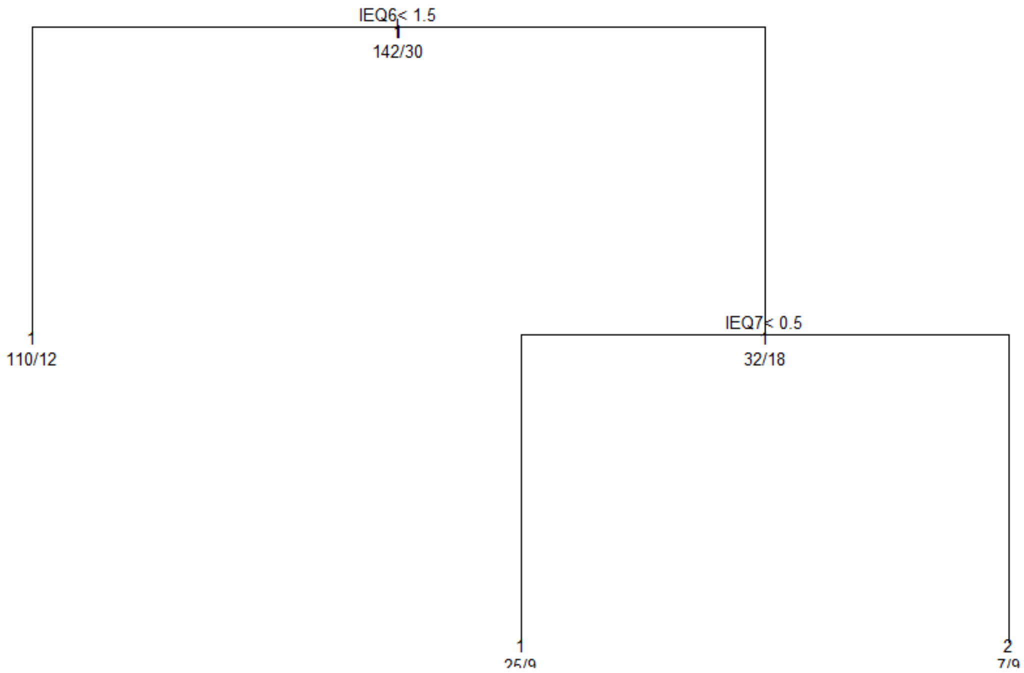
Classification Tree for EA for Platinum Gold Levels



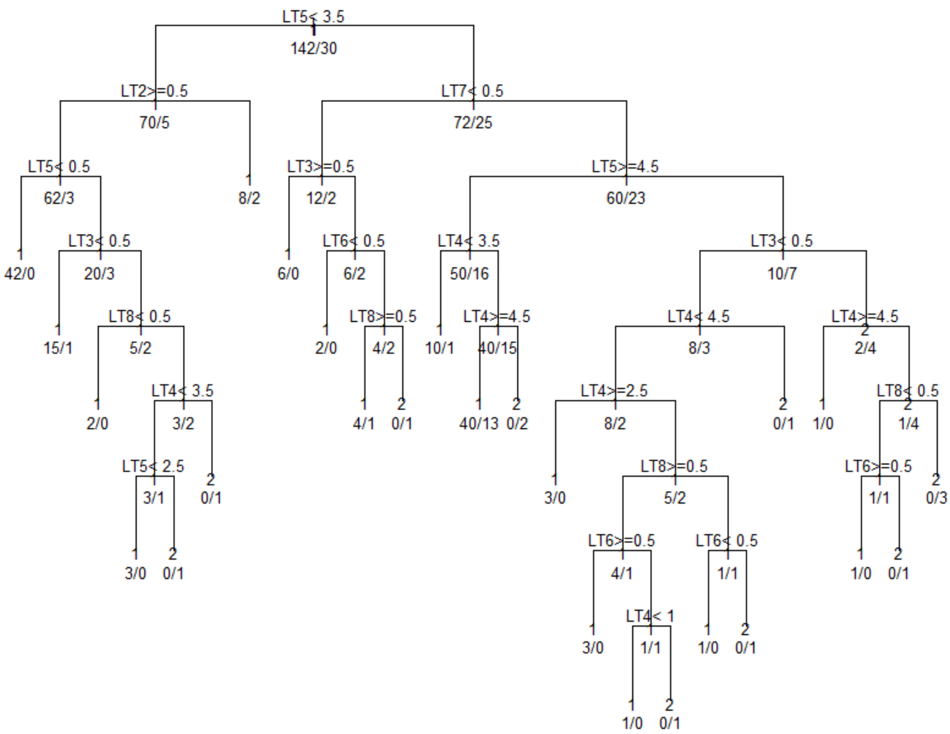
Classification Tree for SS Platinum Gold Levels



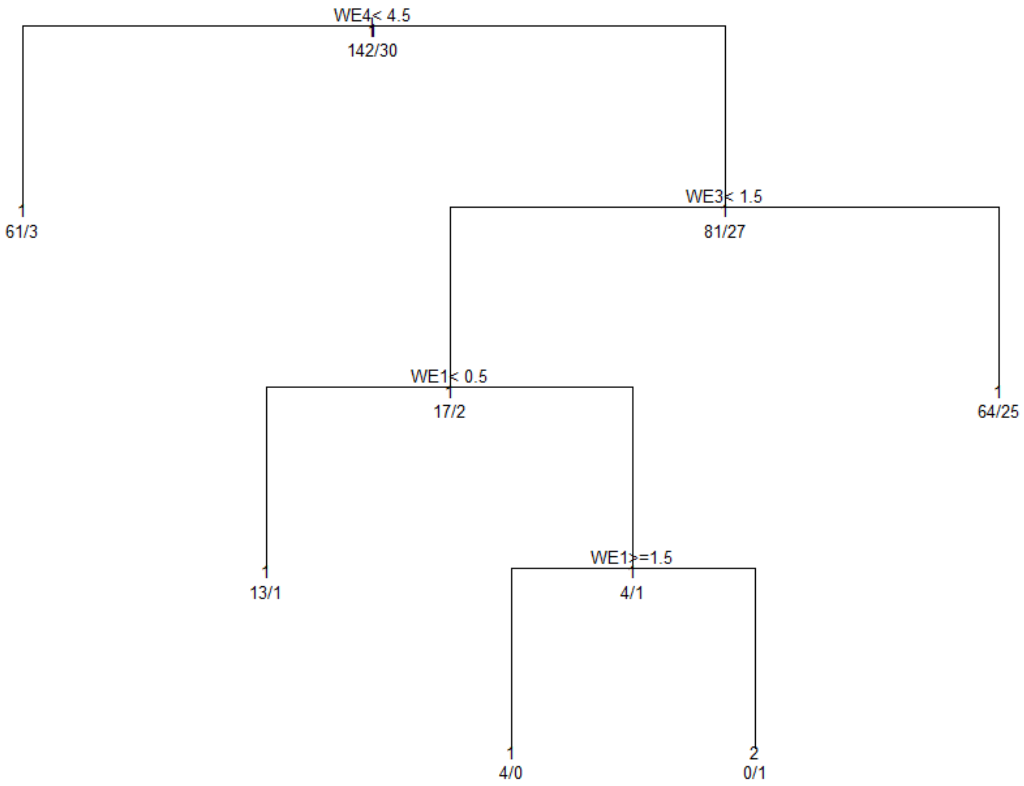
Classification Tree for IEQ for Platinum Gold Levels



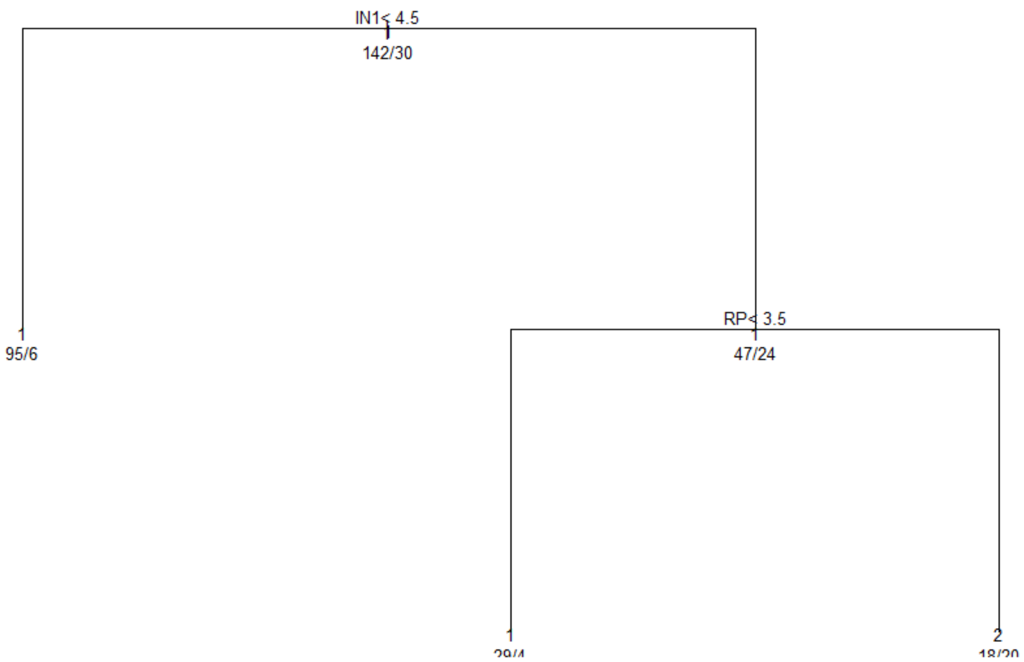
Classification Tree for LT for Platinum Gold Levels

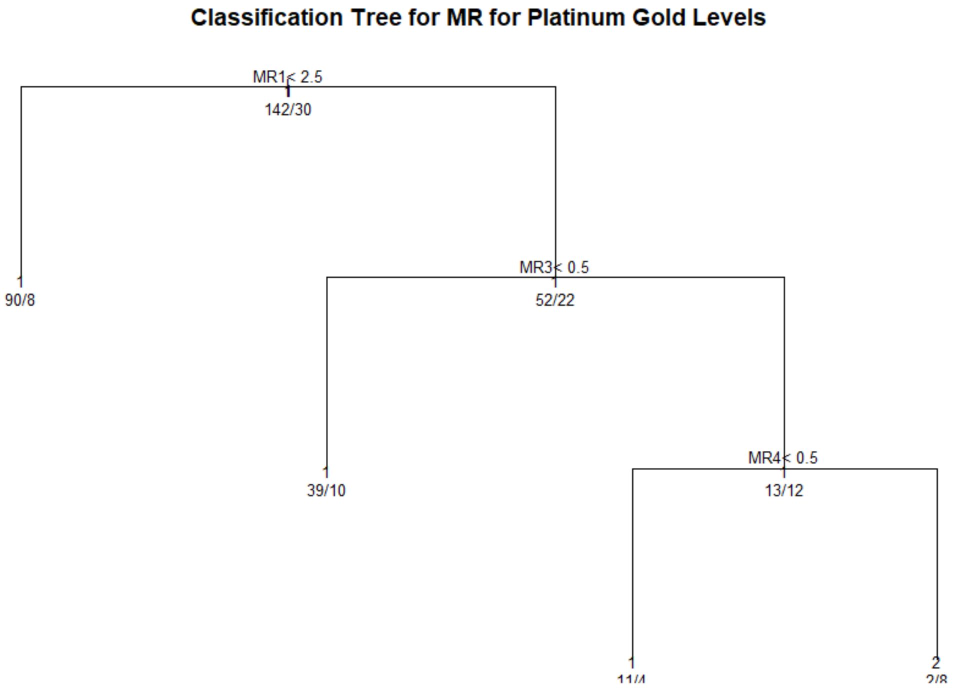


Classification Tree for WE for Platinum Gold Levels



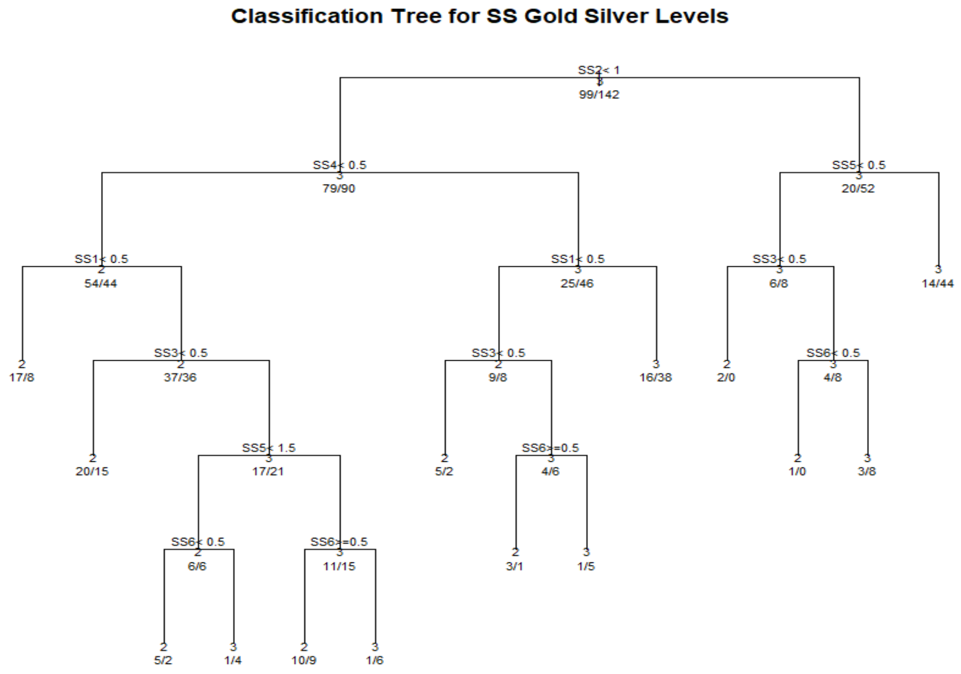
Classification Tree for Innovation and RP Gold Platinum

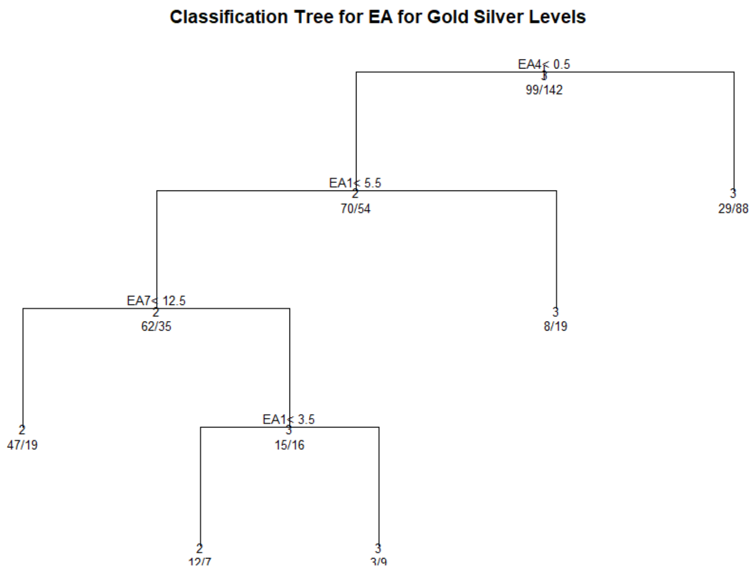



Classification Tree for MR for Platinum Gold Levels
MR1< 2.5
142/30
1
90/8
MR3< 0.5
52/22
1
39/10
MR4< 0.5
13/12
1
11/4
2
2/8

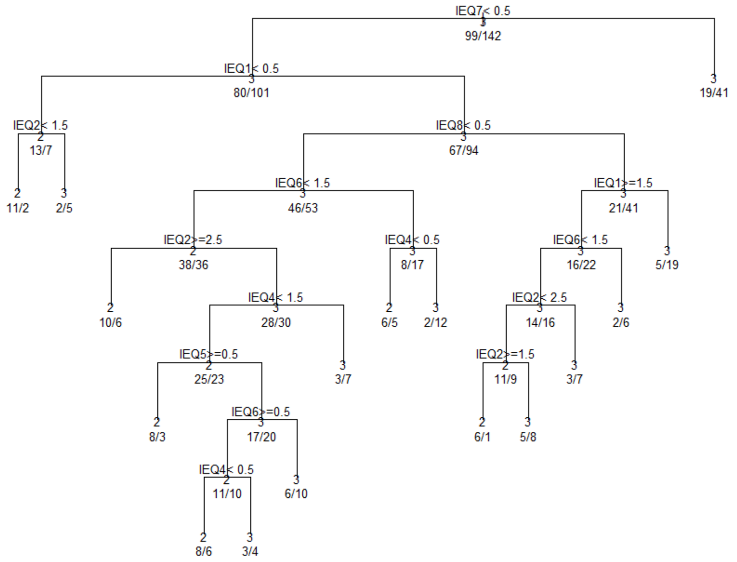
APPENDIX B

REGRESSION TREE PLOTS FOR GOLD AND SILVER PROJECTS ACROSS EACH CATEGORY

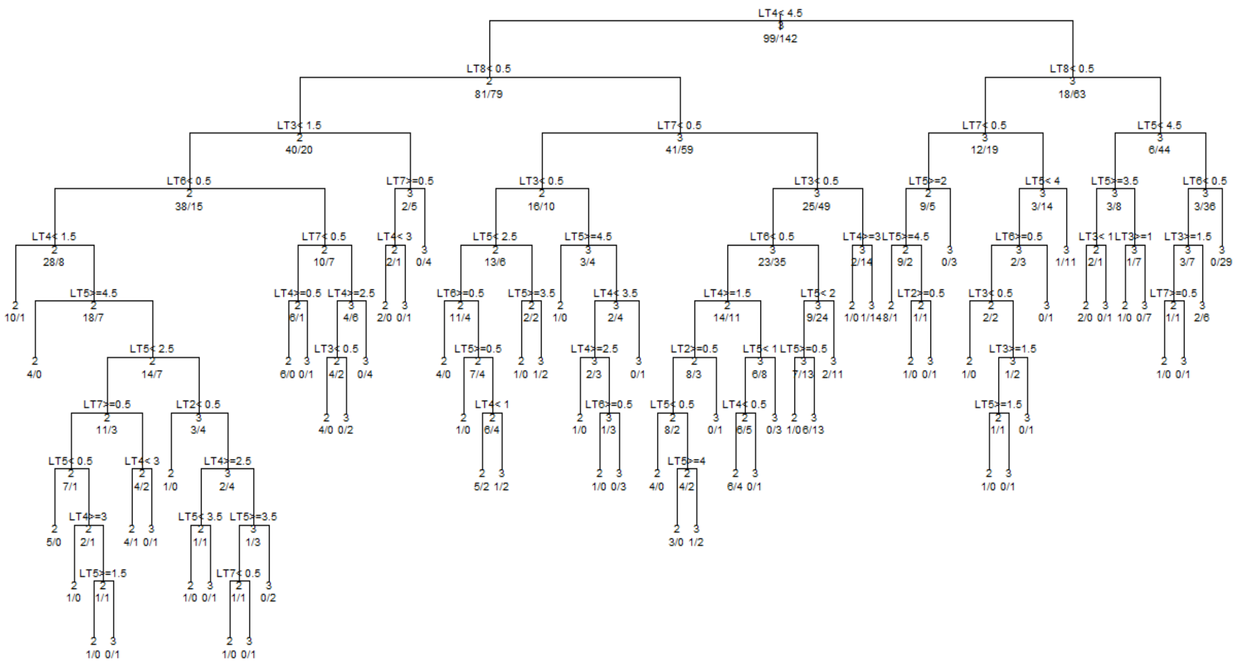




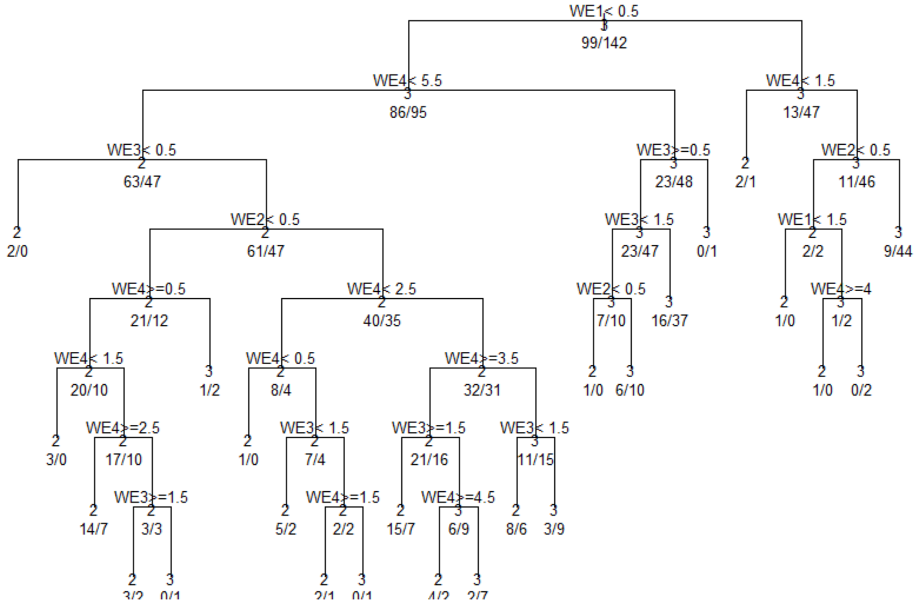
Classification Tree for IEQ for Gold Silver Levels



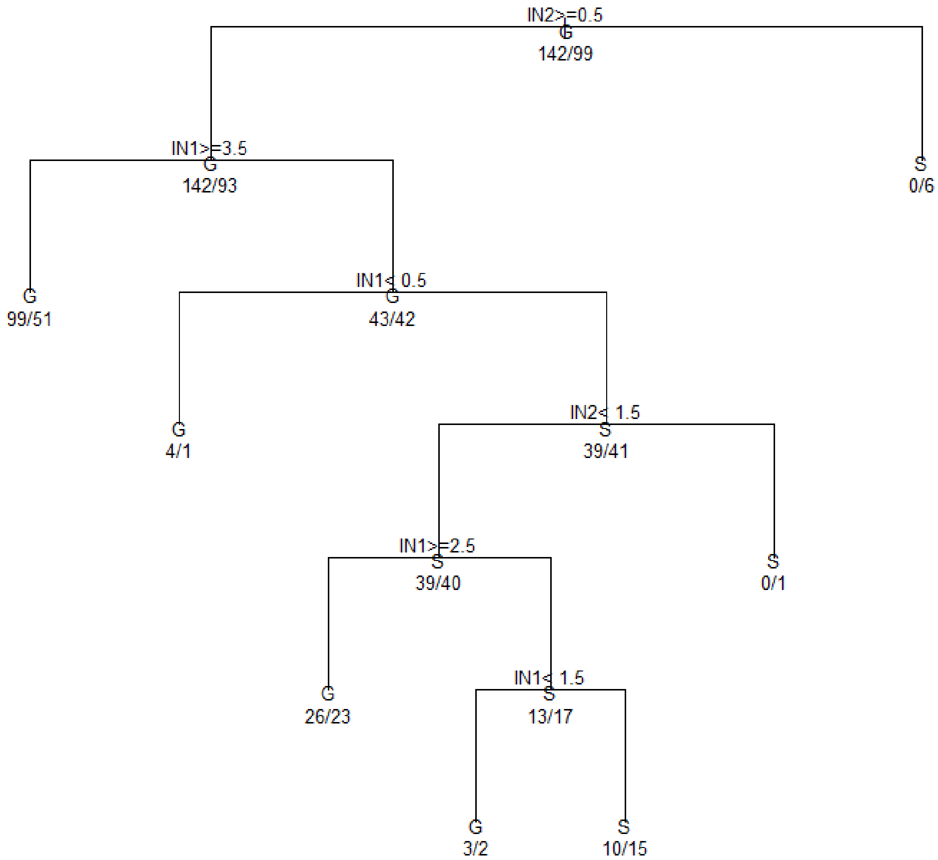
Classification Tree for LT for Gold Silver Levels



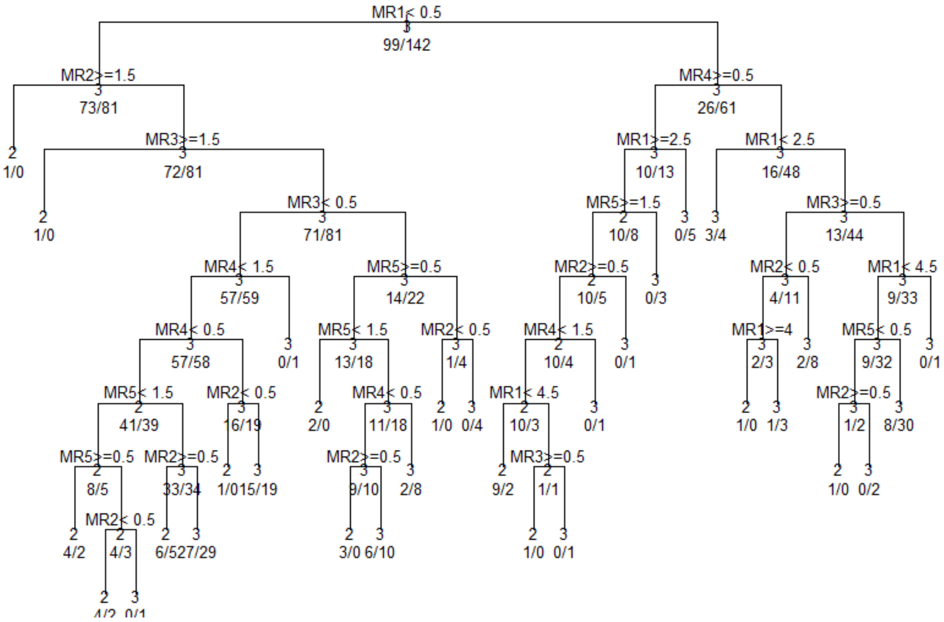
Classification Tree for WE for Gold Silver Levels



Classification Tree for Innovation and RP Gold Silver

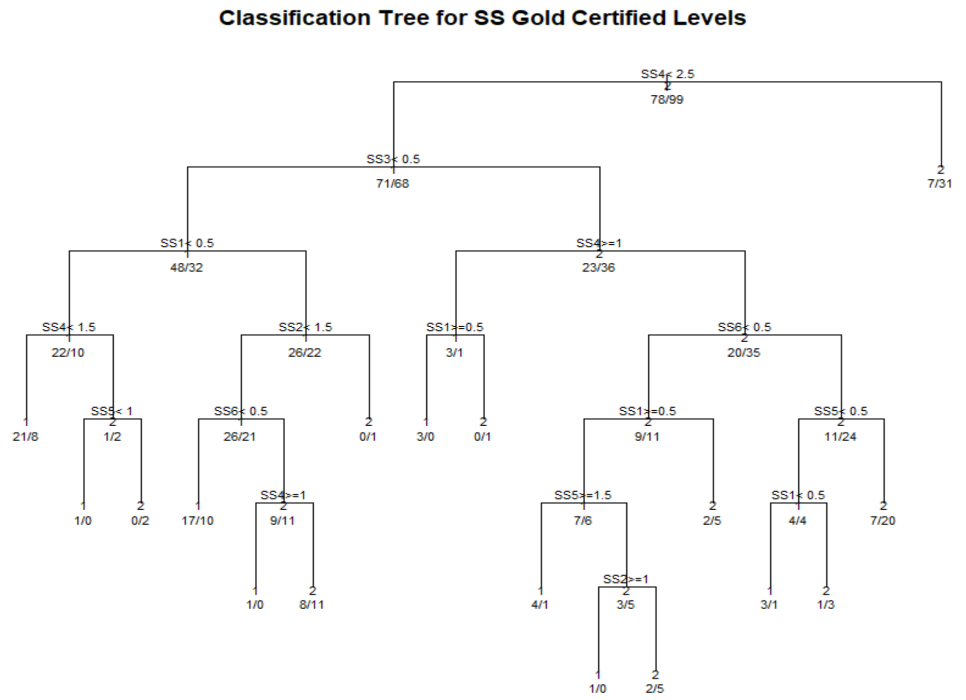


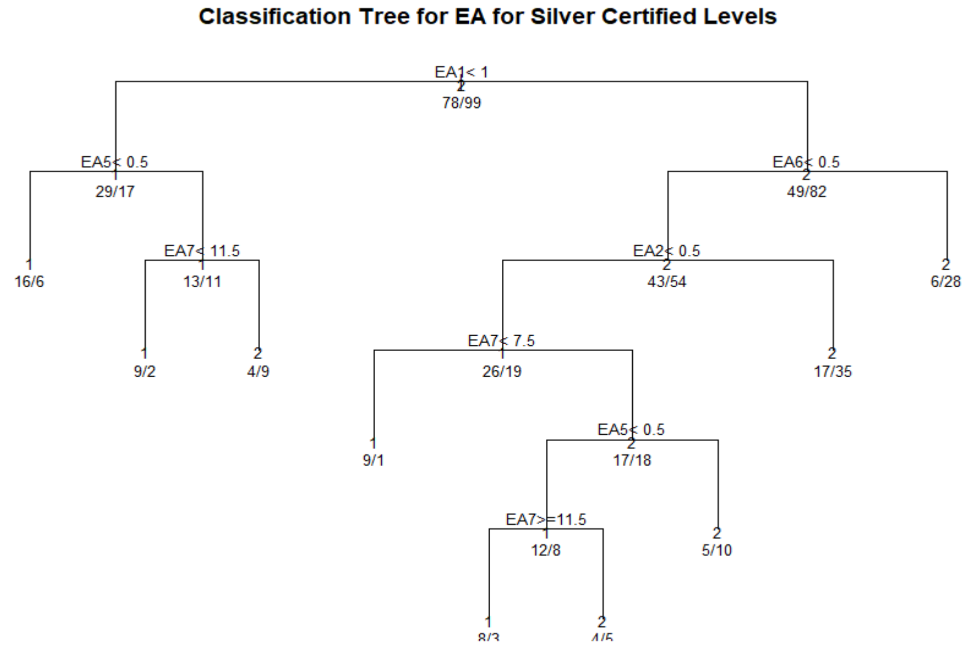
Classification Tree for MR for Gold Silver Levels



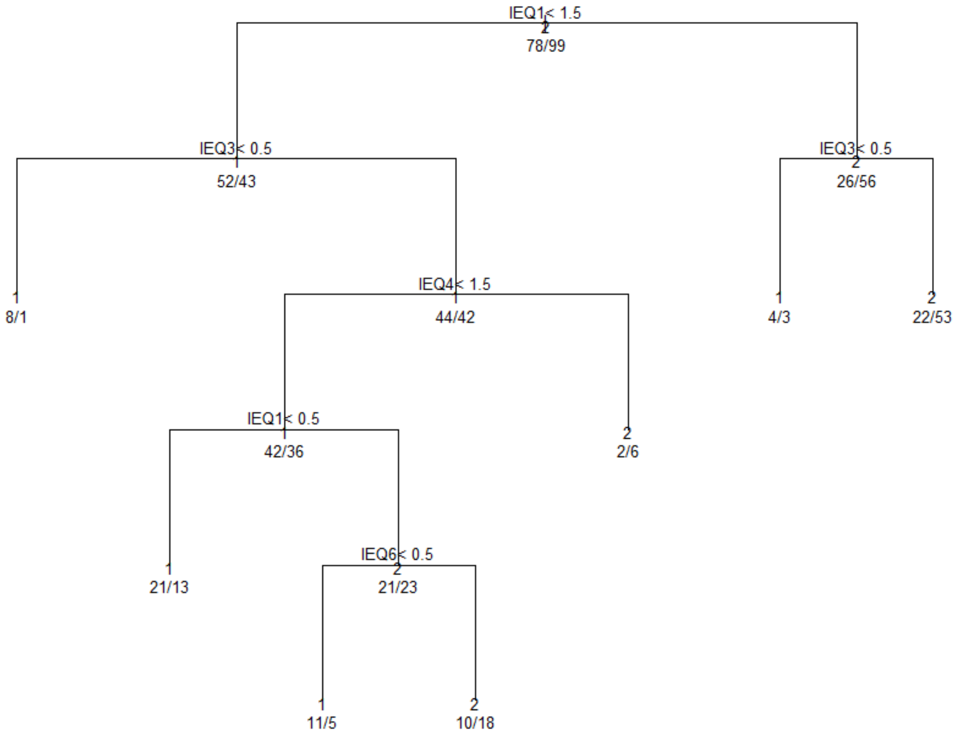
APPENDIX C

REGRESSION TREE PLOTS FOR SILVER AND CERTIFIED PROJECTS ACROSS EACH CATEGORY

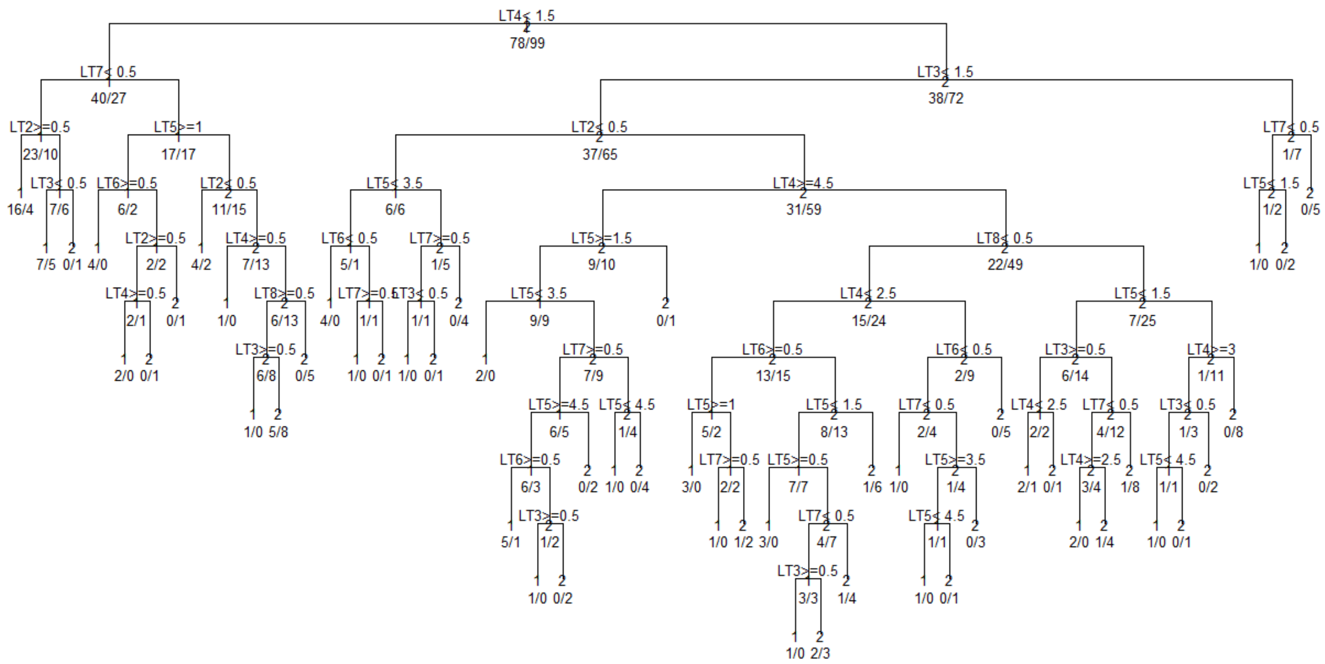




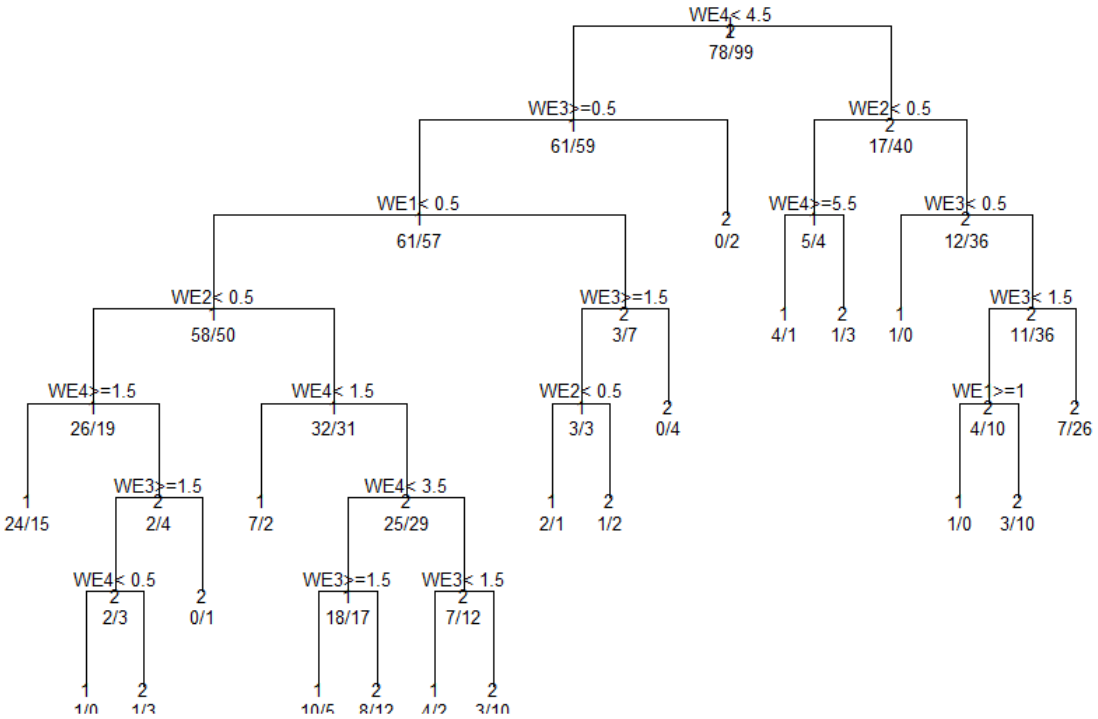
Classification Tree for IEQ for Silver Certified Levels



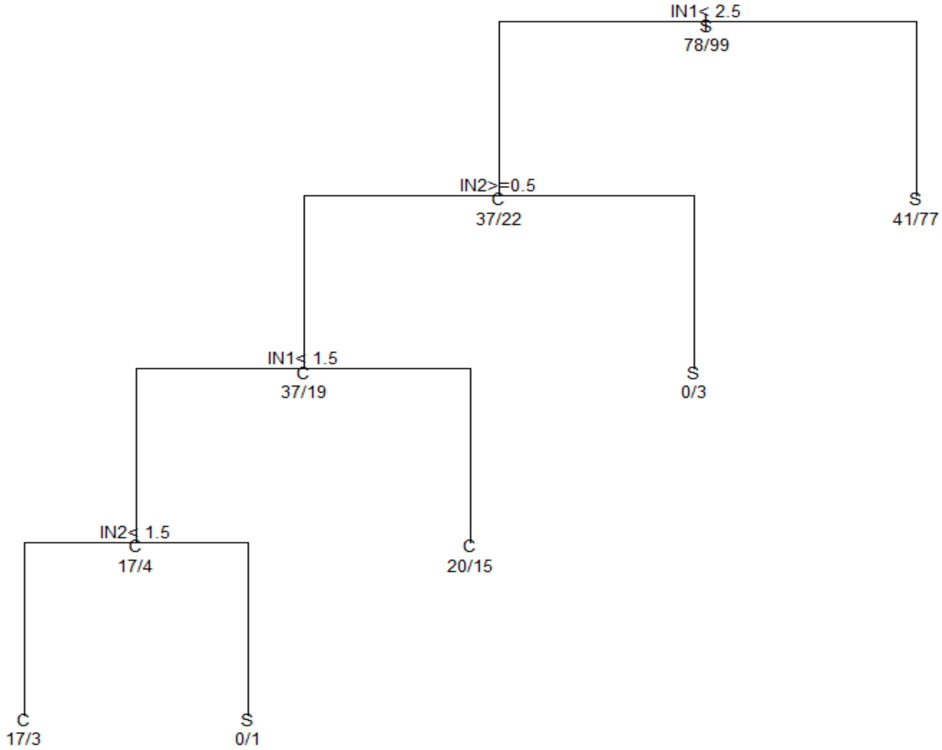
Classification Tree for LT for Silver Certified Levels

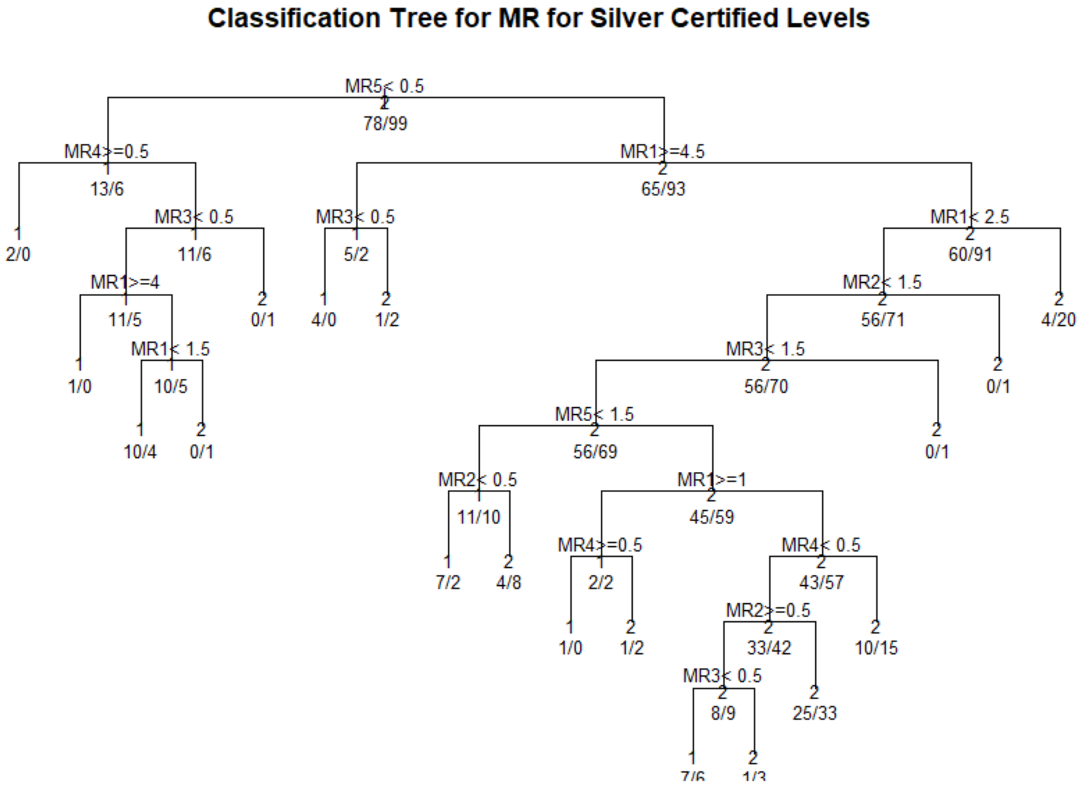


Classification Tree for WE for Silver Certified Levels



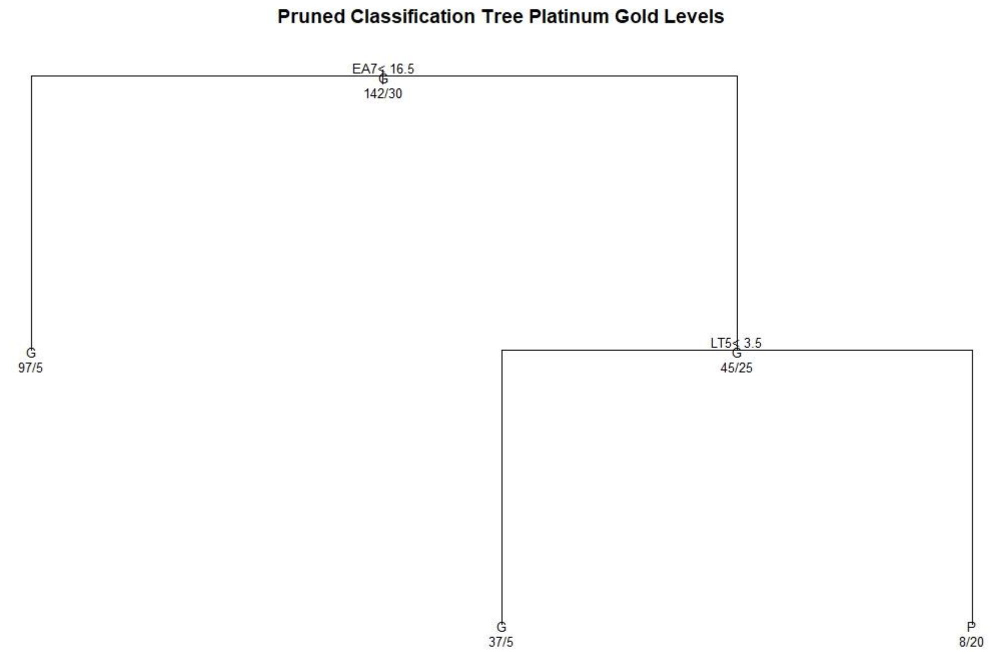
Classification Tree for Innovation and RP Silver Certified

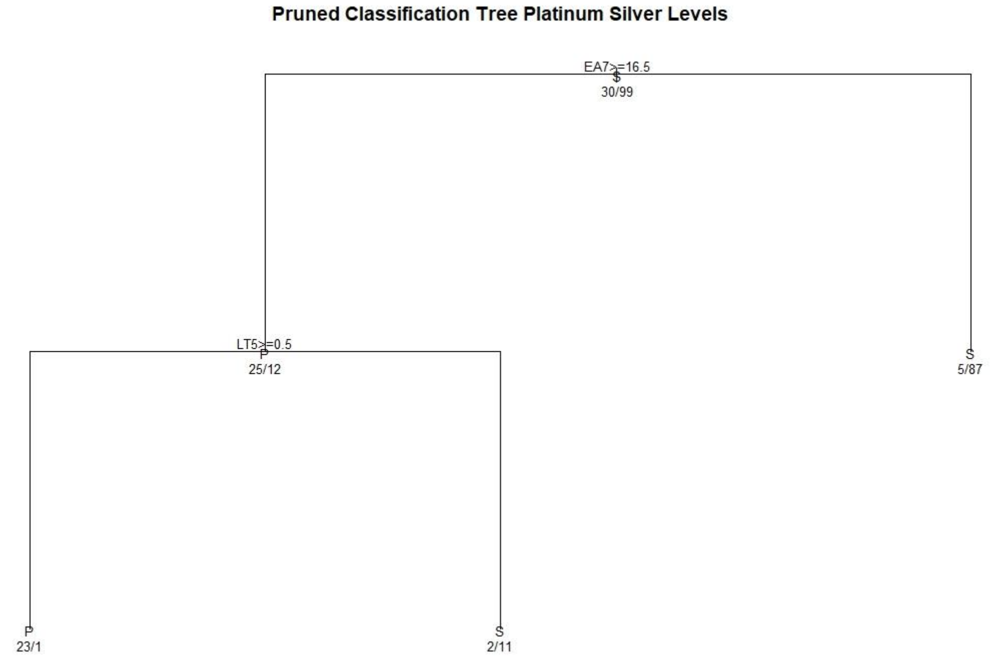



Classification Tree for MR for Silver Certified Levels
MR5< 0.5
2
78/99
MR4>=0.5
1
13/6
MR1>=4.5
2
65/93
1
2/0
MR3< 0.5
1
11/6
MR3< 0.5
1
5/2
MR1< 2.5
2
60/91
MR1>=4
1
11/5
2
0/1
1
4/0
2
1/2
MR2< 1.5
2
56/71
2
4/20
1
1/0
MR1< 1.5
1
10/5
MR3< 1.5
2
56/70
2
0/1
1
10/4
2
0/1
MR5< 1.5
2
56/69
2
0/1
MR2< 0.5
1
11/10
MR1>=1
2
45/59
1
7/2
2
4/8
MR4>=0.5
1
2/2
MR4< 0.5
2
43/57
1
1/0
2
1/2
MR2>=0.5
2
33/42
2
10/15
MR3< 0.5
2
8/9
2
25/33
1
2

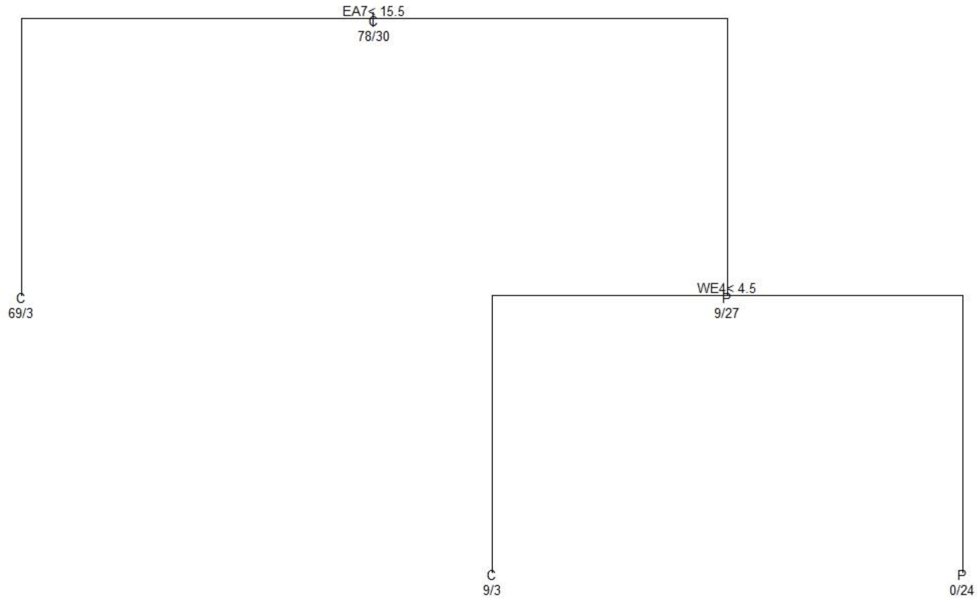
APPENDIX D

REGRESSION TREE PLOTS FOR ALL COMBINATIONS OF CERTIFICATION LEVELS

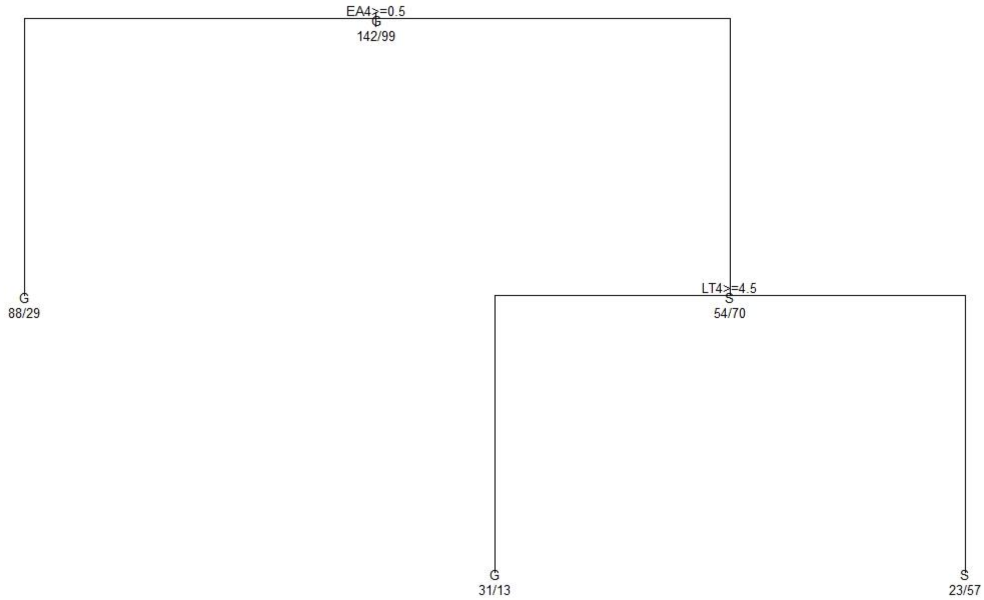


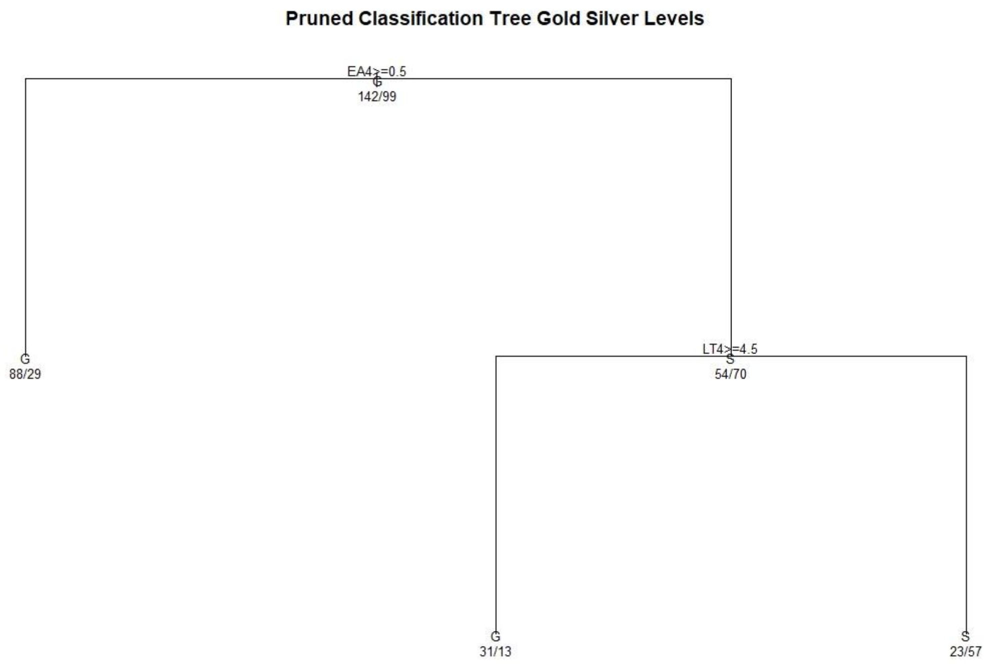


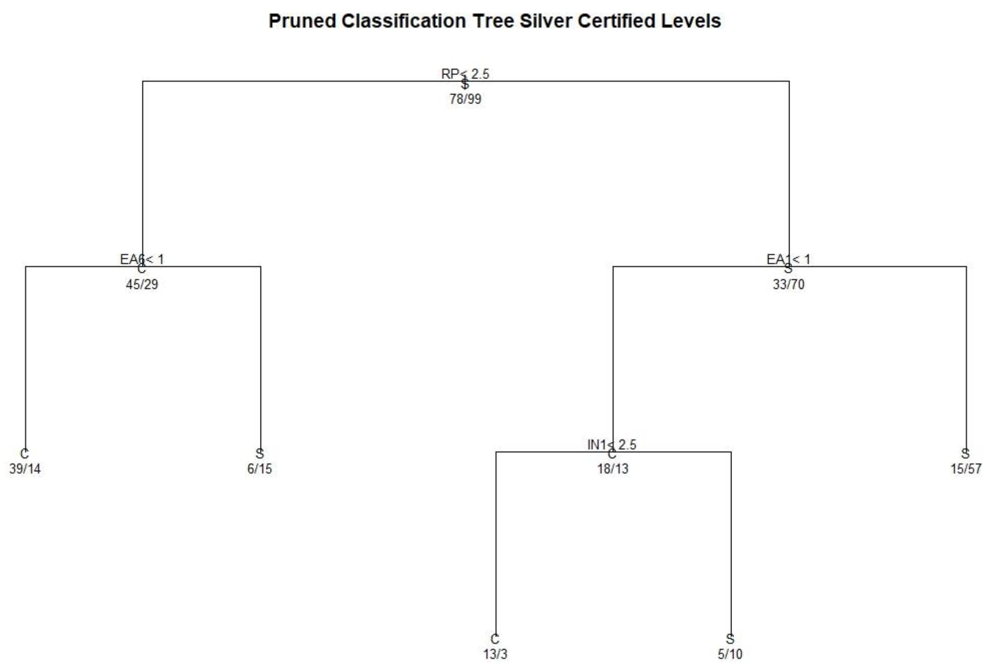
Pruned Classification Tree Platinum Certified Levels



Pruned Classification Tree Gold Silver Levels




Pruned Classification Tree Gold Silver Levels
EA4>=0.5
G
142/99
G
88/29
LT4>=4.5
S
54/70
G
31/13
S
23/57


Pruned Classification Tree Silver Certified Levels
RP< 2.5
S
78/99
EA6< 1
C
45/29
C
39/14
S
6/15
EA1< 1
S
33/70
IN1< 2.5
C
18/13
C
13/3
S
5/10
S
15/57

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