Multi-Criteria Decision Framework for TREES-Certified Green Buildings

Warangkana Juangjandee

Faculty of Architecture, Chiang Mai University 239 Huaykwaw Rd., Sutep, Muang, Chiang Mai 50200, Thailand,
E-mail; warangkana.ju@cmu.ac.th; ORCID: 0009-0008-1970-0652

https://doi.org/10.29227/IM-2025-02-02-095

Submission date: *2025-04-04* | Review date: *2025-05-11*

Abstract

Construction buildings have a significant and continuously increasing impact on the global environment as they consume a lot of resources, energy and contribute a large share of carbon emissions. Green buildings have become a key approach to improve building performance while minimising environmental issues. There are various available green certification schemes, for example LEED, BREEAM, CASBEE, TREES, and Green Mark. However, the cost of green building varies mainly depending on building location. TREES (Thailand Rating of Energy and Environmental Sustainability) is a national green building certification that provides a framework for assessing building performance and built environment sustainability. Despite its advantages, various studies show that green buildings can cost up to 2-4 times more than conventional building constructions. This cost barrier can cause investors and developers to hesitate when considering green construction initiatives. Therefore, green building selection requires a careful trade-off between sustainability and cost. This research uses a mixed -methods approach, integrating the Analytical Hierarchy Process (AHP) with a stochastic cost assessment model to enhance decision-making in TREES-certified building projects. Different levels of TREES-certified buildings are compared, where AHP ranks alternatives based on sustainability criteria, and Monte Carlo simulations assess lifecycle cost variations. The finding indicated that highly sustainable buildings rate higher in AHP but also show larger cost variation due to the use of advanced green technologies, such as photovoltaic, smart metre etc. In contrast, buildings with moderate sustainability ratings and more stable costs may offer a better balance between investment and environmental benefits. This study provides a quantitative decision-making framework aims to help green building developers, investors, and policymakers that minimise financial risks while optimising sustainability.

Keywords: *Green buildings, TREES Certification, Stochastic, Analytical Hierarchy Process, Sustainable building rating systems*

1. Introduction

Buildings are the primary contribution to global environmental concerns, generating roughly 39% of global energy consumption related to carbon emissions [1]. In addition, the construction industry consumes vast amounts of resources and produces waste around 30% of the total weight of building materials [2, 3]. Therefore, with growing concerns, the construction industry has to take proactive action by considering sustainability concepts into its design practices.

A green building (GB) refers to a high performance building that prioritises resource efficiency throughout its entire lifecycle, from design and construction to operation, and destruction. Its shared goals are to provide a healthy both indoor and outdoor environment for occupants while minimising environmental impact and promoting sustainability [4, 5]. GB certification is a tool providing frameworks, requirements and performance criteria to support sustainable development in the built environment. There are various GB certification systems across the world, including LEED (United States), BREEAM (United Kingdom), CASBEE (Japan), Green Mark (Singapore), and TREES (Thailand) [6, 7]. Many buildings aim to pursue certification not only for their environmental sustainability but also to increase their marketability, allowing them to command higher selling prices or rental rates. Despite these possible benefits, certification requirements could create challenges for project teams and could affect productivity in both the design and constructing phase of a green building project [8, 9]. Such challenges may prevent the accomplishment of key project goals regarding to budget, time, and sustainability and frequently remain a major concern for developers and stakeholders.

The selection of appropriate GB certification credits is still being debated, as this decision plays a key role in determining whether a project will meet its sustainability goals. Previous studies have found that built professionals often face considerable challenges when identifying which credits to pursue in new construction projects, due to several uncertainties in interpreting requirements and aligning them with project conditions [10, 11]. Numerous research indicated that making the inappropriate decision in selecting GB certification can lead to a loss of time, budget, and even obtaining the desired GB level [12, 13]. Arun et al. [14] revealed delay causes and additional costs associated with green building accreditation. Rehm et al. [15] emphasised that all of the examined green buildings were greater in cost than conventional ones. In addition, the perceived high cost of GB is a major obstacle for many developers in the decision-making process. Selecting the appropriate target credits that align with the characteristics of a building project from the numerous optional credits within a short period is a challenging and complex task [16]. Furthermore, the same credit can contribute to different levels of green certification but may require varying levels of initial investment [17]. It often requires the GB consultants to rely on their personal experience and knowledge to make decisions and selections. For this reason, the process of GB credit selection is regarded as a critical factor in the success of green building project implementation. Several researchers recommended utilising a well-structured decision-making support tool can mitigate decision making problems [18].

Previous studies have focused on utilising traditional statistical approaches to evaluate credit performance in GB projects under a variety of conditions. For example, Wu et al. [19] applied non-parametric statistical techniques to examine whether significant differences existed in GB credits across different building types and regions. Elbeltagi et.al. [20] used statistical methods and genetic algorithms to explore the integration of parametric design techniques for GB. Similar methods have been used in much research to analyse GB development. However, statistical analysis requires the collection of historical performance data to generate model for different variables. This highlights the

limitation of retrospective analysis, since it does not allow for forward-looking GB credit selection, such as cost efficiency, risk of uncertainty, and the optimal certification level a project should pursue. To address the gap in effective credit selection, multi-criteria decision-making (MCDM) methods have been proposed to develop decision-support tools for GB certification [21]. For example, combining the Delphi method with a multi-attribute utility technique to create a framework for selecting optimised credits. Many researchers used surveys and interviews to support decision-making in green construction projects. While surveys and interviews are widely used, it remains highly dependent on expert judgment for assigning attribute weights and does not fully account for building-specific or contextual factors. MCDM method can be used to deconstruct the problem of decision making. MCDM methods can provide a systematic and objective framework for deconstructing complex decision-making problems [22]. MCDM enables the comparison of the relative importance of various criteria and supports the selection of the optimal options through mathematical modelling. MCDM techniques help clarify the interrelationships between criteria and minimise the subjectivity typically associated with expert-based selection.

Contextual factors such as site location, climate, environmental conditions, and local construction practices play a crucial role in determining the most suitable GB strategies. These factors influence how different certification credits prioritise their evaluation criteria. For instance, LEED mainly focuses on energy performance, which account for up to 33% of the total score. LEED can be adopted to different climates. Although the cost of hiring LEED-accredited consultants is often expensive, it might be a barrier for some projects. BREEAM is another standardised GB credit system, with many of its credits designed for temperate climates. BREEAM also emphasises energy performance, approximately 30% of the total credit score, but gives relatively greater weight to other categories such as management, health and well-being, and material selection. These distinctions reflect the differing environmental priorities, local regulations, and assessments. Thailand has a tropical climate, which requires specific consideration of cooling loads, humidity control, and rainwater management. The GB rating system selection tools must be tailored to meet local environmental and operational needs. TREES (Thailand Rating of Energy and Environmental Sustainability) is Thailand's national GB certification system, providing a framework for evaluating building performance and sustainability in the built environment. TREES was modelled from the LEED framework, but TREES has been tailored to Thailand's climate, environmental conditions, and construction practices. Several studies have found that TREES incorporates a wide variety of challenges, including technology, environmental effect, economics, social responsibility, and project management. While advanced green technologies can improve building sustainability, their impact depends on stakeholders' capacity to implement them effectively. However, having access to such technologies does not guarantee the technical ability to implement them in practice. Furthermore, research on decision-making processes within the TREES framework remains limited. Further study is needed on how decision-making influences TREES credit selection.

This study aims to identify the optimal TREES certification option through a mixed-methods approach that analyses the trade-off between investment costs and environmental benefits. It seeks to develop a quantitative decision-making framework to support GB developers, investors, and designers in minimising financial risks while maximising sustainability.

2. Literature Review

2.1 TREES certification

The TREES rating system consists of eight sustainability categories. TREES certification includes nine mandatory prerequisites, while projects may achieve for up to 100 points through various rating categories. The system enables four certification levels based on the total score achieved: Certified, Silver, Gold, and Platinum.

TREES is designed to be adaptable and relevant to all building types and phases, including new construction, major renovation, existing buildings, core and shell buildings, and operations and maintenance. Under TREES-NC/CS v2, the eight categories and their maximum point allocations are in Table

Tab. 1. TREES certification categories and points

TREES Categories	Prerequisite	Maximum point
Building Management (BM)	1	3
Site and Landscape (SL)	2	18
Water Conservation (WC)	-	6
Energy and Atmosphere (EA)	2	30
Materials and Resources (MR)	-	13
Indoor Environmental Quality (IEQ)	2	18
Environmental Protection (EP)	2	6
Green Innovation (GI)	-	6

2.2 Study Cost for Green Building Model

GB development has increased attention for much research. Questions surrounding the initial investment required for GB implementation continue to raise concerns among GB industry stakeholders, which potentially limits widespread adoption.

A quantitative study by Rehm and Ade [15] examined the impact of green building construction costs. The research focused on construction cost, such as materials, equipment, and labour and operation costs, including project management, government fees, and design services. Several studies have compared actual GB costs with those of conventional projects, and the findings generally indicate that green buildings are more expensive to build. Moreover, the GB cost tends to rise with higher levels of certification. For instance, one of the previous analytical studies found that achieving the Platinum level of certification resulted in a cost increase of approximately 21% over conventional construction. Tatari and Kucukvar [23] developed a neural network model that estimated initial construction costs based on the correlation between each LEED certification category. Their model revealed that additional cost increases of 0.66%, 2.11%, 4.41%, and 6.5% for LEED Certified, Silver, Gold, and Platinum levels, respectively. Other studies have reported cost increases ranging from 4% to 21%. Additionally, a study examined around 100 prior green construction projects and found that construction delays in GB projects were roughly twice those of conventional buildings.

The lack of a database for estimating additional green costs has been identified as a major concern. Additionally, the GB cost assessment should not only explore only initial cost but should also include operation cost. Alshamrani and Alshibani [24] proposed analysing four primary cost components for life cycle cost (LCC) assessment: initial costs, annual running costs, including operations, energy, maintenance, and major repairs, environmental impact costs, and salvage value. Wenxin Shen [25] developed a survey combining categories of TREES and LEED to evaluate barriers to GB adoption. The findings showed that high initial costs and a lack

of motivation from building owners were the two most significant obstacles to GB growth.

Researchers have used multi-criteria decision-making (MCDM) approaches to help with difficult decisions such as credit selection and cost-benefit analysis. The Analytic Hierarchy Process (AHP) is one of the most widely used. AHP allows decision-makers to evaluate multiple criteria in structured, quantitative methods and to identify the most optimise alternatives. It is particularly useful for addressing GB construction-related decisions, which often involve numerous interrelated and nonlinear factors [26, 27]. Additionally, Al Awam [28] applied a stochastic approach to simulate and compare LEED certification levels across different building types to support decision-making. However, the study did not account for the proportional weighting of individual categories, limiting its ability to guide optimal credit selection. A stochastic method uses probability distributions for input variables, resulting in a range of possible outcomes rather than a single value. The stochastic method offers a more accurate understanding of cost variability and performance uncertainty in GB projects.

2.3 Summary of Limitations

Previous studies have explored through different aspects of GB development, including certification level, initial cost, and challenges related to implementation. These studies have provided significant contributions, notably to the development of initial construction cost model assessment across various countries. However, reported cost premiums vary significantly, influenced by factors such as location, building type, certification system, target certification level, and the specific green credits applied.

Despite the range of existing research, several limitations remain. Particularly, there is limited investigation into the initial costs and LCC costs associated with TREES certification, the weighting system for credits, and the use of quantitative methods to support decision-making. Furthermore, few studies address uncertainty in cost assessments or propose integrated frameworks suitable for context-specific decision-making in the Thai construction industry.

To address these gaps, this study aims to develop a decision-making framework for TREES certification by integrating the Analytic Hierarchy Process (AHP) with a stochastic cost assessment model. The research focuses on evaluating the risks and cost uncertainties across different TREES certification levels. The total projected costs for each certification level will be compared and provided as data-driven decisions.

3. Methodology

3.1 AHP Model Development

The Analytic Hierarchy Process (AHP) is a decision-making tool to prioritise sustainability criteria. Traditional AHP methods have been widely used in GB assessments, as they offer a systematic framework for evaluating qualitative and quantitative factors through pairwise comparisons. However, conventional AHP often relies on expert opinion, which can be inconsistent and subjective in the weighting process. Thus, the Entropy-AHP is another method that integrates entropy weighting into the hierarchical structure of AHP. The entropy method is data-driven and more objective weights based on the variance of information among options. The Entropy-AHP method allows for a more balanced and credible evaluation of GB certification criteria.

The Entropy-AHP method was applied through a systematic step to evaluate sustainability criteria and certification options. First, a decision matrix a decision matrix $X=[x_{ij}]$ was constructed, where x_{ij} represents the performance score of alternative i under criterion j. This matrix was then normalized using the formula as follow

$$p_{ij} = \frac{x_{ij}}{\sum x_{ij}} \tag{1}$$

where p_{ij} is the normalised value of the performance score. Then, the research focused on computing entropy for each category. The entropy value for each criterion was calculated using following

$$e_j = -\frac{1}{\ln(m)} \sum_{n}^{m} p_{ij} \ln(p_{ij}) \tag{2}$$

where e_j represents the entropy of criterion j and m is the number of certification levels.

The research was then compute the weight for each TREES category. The weight for each criterion is determined by:

$$w_{ij} = \frac{1-e_j}{\sum_{j=1}^{m}(1-e_j)} \tag{3}$$

These entropy-derived weights w_j are then used to construct the weighted decision matrix by multiplying each normalised score p_{ij} by its corresponding weight. In terms of cost-related uncertainty, an additional criterion is the Cost Stability (CS) score, which is determined using stochastic cost simulations. This score varies between 0 (least stable, highest risk) and 1 (most stable, lowest risk). The CS score was weighted depending on historical data of stakeholder and existing research and then incorporated into the final weighted decision matrix.

3.2 Stochastic Cost Assessment

Firstly, this study examines the economic performance of TREES certification in an office building with a useable floor area of 10,000 sq. m. The assessment includes both initial investment costs and operational costs. The initial cost assessment covers construction-related expenses such as building materials, labour, equipment installation, professional service fees, and fees associated with TREES credit implementation. The operational cost analysis includes maintenance, annual utility bills, and projected energy and resources saving improvements. The cost estimates were developed using data from Thailand Construction Material and Labour Cost Index, previous studies, national building regulations, available TREES-certified project data, and other cost references relevant to GB development.

The evaluation method involves estimating and comparing the total investment costs, annual operational costs, and potential returns associated with each TREES certification level (Certified, Silver, Gold, and Platinum). This comparison will be used to analyse the cost-effectiveness and financial risk associated with pursuing higher levels of sustainability.

Monte Carlo simulation method was then applied to generate 1,000 cost scenarios. This approach allows for a probabilistic understanding

of cost variability, resulting in a distribution of total project costs. This method can reflect the uncertainty in real-world GB cost and provide financial risk level. A multi-Criteria Decision Framework was developed by integrating of AHP and stochastic cost modelling to evaluate GB certification options under the TREES framework. This approach can establish the comparison between environmental sustainability and financial risk. (see Fig. **1**)

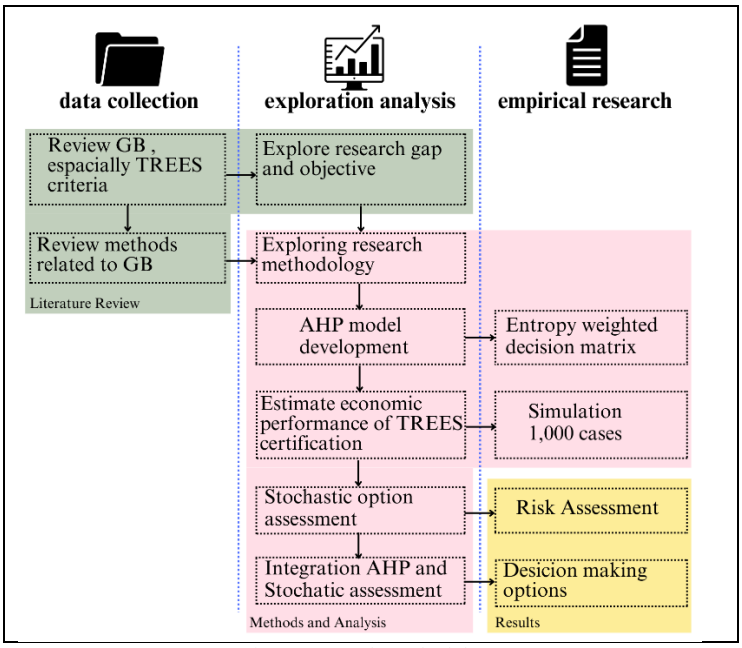

Fig. 1. Research Methodology

4. Results and Discussion

4.1 Entropy-weighted decision matrix

The entropy-weighted decision matrix was applied to identify the relative importance of each TREES certification category. The resulting weight distribution reflects the proportional each criterion of TREES (see Fig. **2**). The weight of EA was the highest at 28.1%, emphasising its importance in performance evaluation, especially in tropical climate like Thailand. SL and IEQ were with a weight of 16.8%, while MR was assigned 14.0%. WC and EP showed the least variation, both weighted at 5.6%. CS factor was weighted at 13.0%, indicating its relevance in balancing environmental performance with economic uncertainty.

When evaluating GB certification categories, the Weighted-Decision Matrix should combine both environmental sustainability with cost consideration. Previous studies rarely applied weightings for economic factors in Multi-Criteria Decision-Making frameworks within GB assessments. Economic considerations are acknowledged as important, specific percentages are seldom mentioned. Illankoon et.al [29] recommended cost stability should be identified in the weighting credit criteria for the GB rating tools. The green building cost variability is suggested to be approximately between 10% and 15% of the total cost [30].

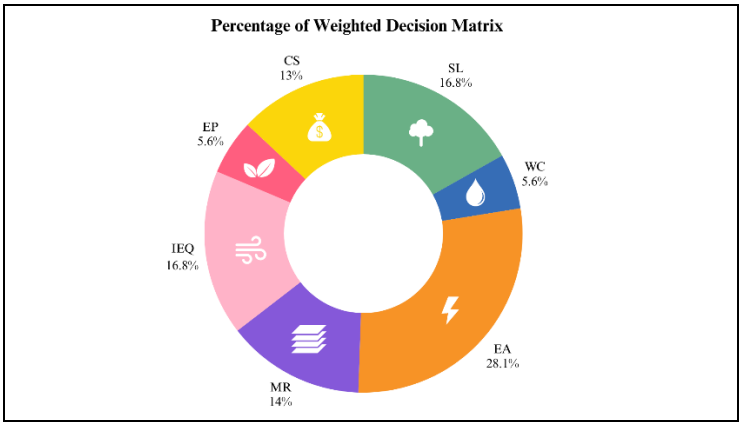

Fig. 2. Percentage of Weighted Decision Matrix

4.2 Stochastic Cost Assessment results

4.2.1 Cost Assessment. The initial costs were assessed across TREES categories including construction cost and fee for four certification levels (see Fig. 3): The result showed that the fee costs increased approximately 2% compared to conventional building. The fee cost of different credit levels were slightly variation due to documentation requirement, and consultant services. EA showed the highest increase, particularly for Platinum, reaching nearly 6.5%, followed by Gold and Silver. EA accounts for the largest proportion of additional costs, representing approximately 60% of the total increase. This demonstrated the investment in high-performance technologies such as HVAC optimisation, smart metering, and renewable energy systems. An additional 2.8% cost gap of IE between Gold and Platinum revealed that achieving top-tier indoor quality involves not only advanced design solutions but also premium materials and technologies. MR provide remarkable decrease in cost for Platinum, potentially due to the use of recycled,

reused or locally sourced materials. This can reduce procurement and transportation costs and may offer returns during construction. SL, WC, EP, BM showed relatively negligible or stable cost changes, especially EP, which reflects low capital cost since its improvements often involve substitutions rather than new installations.

The finding in this study revealed that the total initial costs increased from the conventional building initial cost were 4.93%, 6.12% 10.97% and 14.79% for Certified, Silver, Gold, Platinum respectively. The range of additional GB cost were similar to the previous studies. For example, Dwaikat [13] found that the green cost premium that can be in ranges from 4% to 21%.

In order to achieve higher green certification levels, the GB projects is not only required to use advanced energy system but also require higher capital investment [31]. Sun et al. [32] provided that the major factors influencing on the additional costs of GB were: renewable energy application (48.20%), saving energy of envelope structure (23.20%), building intelligent (16.10%), indoor environment control (7.5%), water utilization and rainwater collection (2.60%). Another study found that the incremental cost ratio was 1%, 2.2% and 3.4 % for achieving one-,two, and three- star green building lebe [33]. Nalewaik and Venters [34] confirmed that the cost increased due to the GB premium. Tatari and Kucukvar [23] explored the additional cost related to LEED rating system and found that each certification level at 0.66%, 2.11%, 4.41%, and 6.5% for certified, silver, gold, and platinum levels, respectively. Another research also indicated that GB certification cost added up to 2.5%, 3.3%, 5.0%, and 4.5–8.5% for certified, silver, gold, and platinum levels, respectively [35]. Regarding the research finding research and relevant research, achieving higher levels of GB certification often entails a significant increase in initial investment, which is driven by the integration of advanced technology and compliance with performance standards. Multiple studies support this trend, consistently showing that green building premiums rise with each certification level. The incremental cost increases for GB certifications ranging from 0.66% at the Certified level to 6.5% at Platinum. Similarly, other studies report comparable cost ranges, with Platinum-level certification incurring the highest additional cost, reaching up to 8.5%. When GB project targets higher tiers of green certification, the incremental cost would occur.

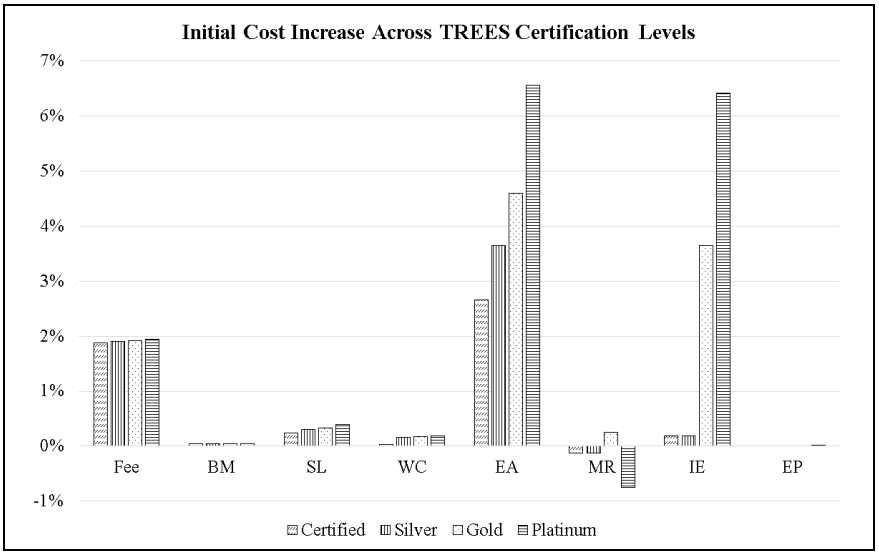

Fig. 3. Initial Cost Increased Across TREES Certification Levels

4.2.2 Payback period. Although the initial construction costs increase with higher levels of GB certification, particularly at the Platinum level. The investment is compensated over time through operational savings. As mentioned previously, higher-tier certifications typically require the integration of advanced technologies, which contribute to the upfront cost. The finding reveals that the payback period of all GB levels are within 10 years. The conventional buildings started with the lowest initial cost, with 160 million THB for year 0. Platinum-certified buildings began at around 175 million THB, reflecting the higher capital investment required for advanced green features. Certified and Silver buildings had moderately higher initial costs. However, these features significantly reduce utility expenses during the building's lifecycle. The analysis of the payback period revealed that the investment in green technologies begins to return value within 3 to 8 years depending on the certification level. The payback periods for Certified and Silver levels are shorter due to lower initial GB premiums, while Gold and Platinum take longer but provide greater long-term savings and environmental benefits. However, operational savings accumulate, particularly from reduced electricity consumption, water saving, water measures, and renewable energy production can provide cost compensation. Silver buildings got the fastest return after three years while Certified spent four years for the return periods. Gold-certified buildings reached around year 6. For Platinum-certified buildings, cumulative return cost were 8 years (see Fig. 4).

Relevant study also found that operation costs were approximately 0.84% to 1.31% of total construction costs. Furthermore, the reduction in annual energy consumption costs was estimated at 31% to 40%, and the payback period ranged from 0.41 to 2.56 years [36]. The incremental benefits and costs were analysed for 33 LEED-certified green buildings [37]. The findings indicate that the total financial benefits of GB were more than ten times greater than the average additional initial investment. Notably, solely energy savings exceeded the average incremental costs confirming that GB is not only environmentally beneficial but also cost-effective and financially concern. Luchkina [38]developed a cost projection model that integrates comprehensive energy-efficient technologies and other parameters. The results demonstrated a net present value (NPV) proposed project pay off. The payback period of the Energy Efficient GB project was within 10-29 years and an internal rate of return (IRR) of 13.9%, indicating strong economic feasibility. This period demonstrates a relatively short duration of green investment return.

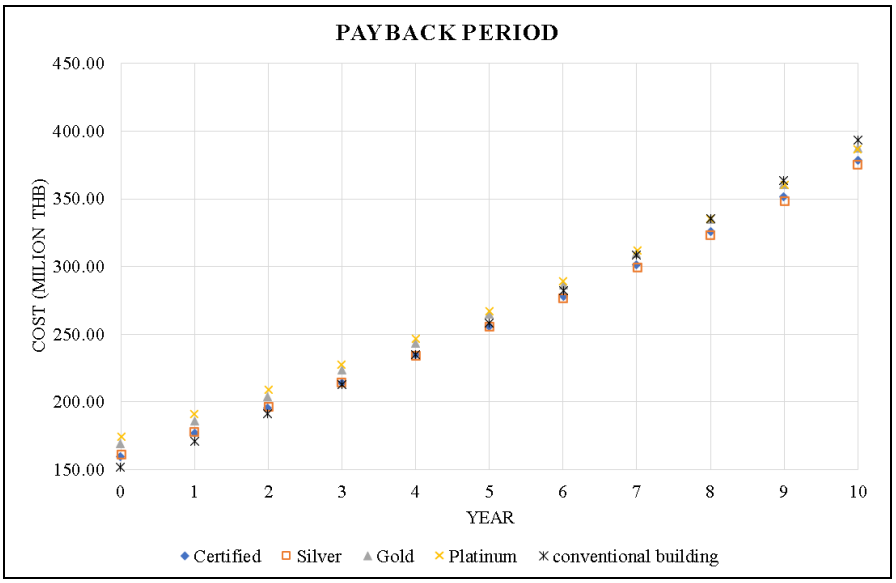

Fig. 4. Comparison of Payback Periods

*4.2.3 Cumulative probability distributions***.** The cumulative probability distribution in Fig. 5 presents the range and variability of total costs associated with four TREES certification levels. The cumulative probability from 0% to 100%. The graph shows that Certified buildings have the widest distribution, indicating the greatest cost uncertainty, with total costs spanning roughly 90 to 160 million THB. In contrast, Silver-certified buildings display the narrowest range, with most outcomes tightly clustered between 120 and 150 million THB, suggesting higher cost predictability and stability. Gold and Platinum show increasing cost medians. The level of cost risk of Silver and Gold imply tighter cost ranges, while the Certified and Platinum suggest higher variability in implementation costs.

This figure emphasises major trade-offs between certification level and cost stability. While higher certification levels demand a larger initial investment, they tend to show more predictable cost outcomes, especially in the Silver and Gold categories. Conversely, although Certified buildings may begin with a lower average cost, the larger distribution signals greater financial risk due to uncertainty. As a result, when cost stability is included in a multi-criteria evaluation framework, such as the integration of AHP-stochastic model and Stochastic, Silver and Gold certifications appear as the optimal options. This can provide the balance both sustainability targets and financial.

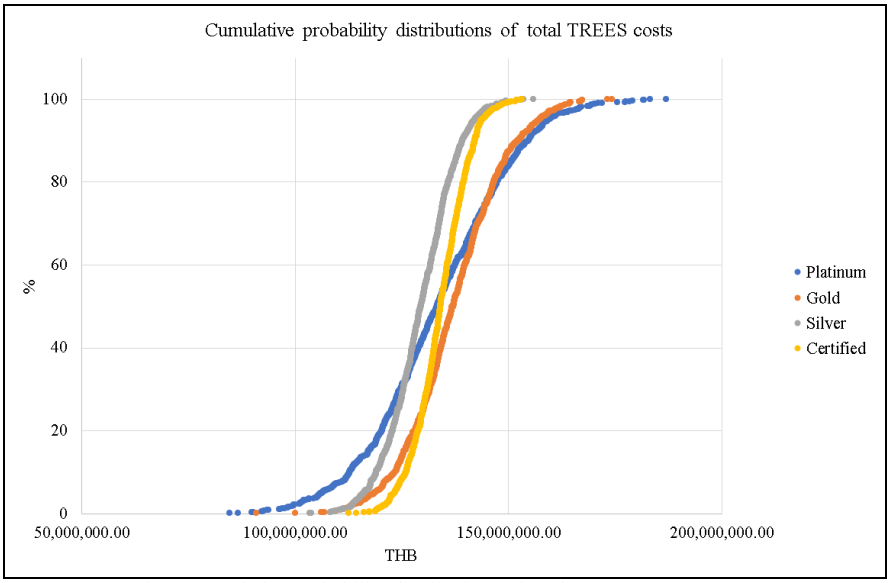

Fig. 5 Cumulative probability distributions of total TREES costs

The integration of AHP and stochastic cost modelling provides a multi-dimension perspective on GB certification for evaluation outside simple cost or sustainability rankings. The AHP component helped identify EA, IEQ, and SL as top-priority criteria based on the TREES framework. However, the prioritisation related to the framework is insufficient. Therefore, the stochastic model was introduced to analyse financial variability and cost reliability. The cumulative probability distributions provided valuable insight into the possibility of overall project cost across certification levels. While Platinum buildings achieved environmentally greater in AHP weighting, exhibited broader cost distributions. This suggested higher uncertainty and potential financial exposure. On the other hand, Silver-certified buildings were indicated greater predictability and cost stability. The Certified level showed the highest variability, which may inhibit investment owing to less predictable returns. For the payback period analysis, these findings further differentiate the certification tiers. Silver level got the fastest return that can provide the optimal balance between sustainability and cost uncertainty risk. The optimal case would motivate the stakeholders to integrate GB framework in their project and might increase the growth of GB implementation. Although Platinum projects

demand the highest capital, their long-term operational savings eventually reduce cost gaps by year 8. In practical terms, this integrated method reveals that optimal certification choices are not those with the highest sustainability scores, but rather those that balance cost risk.

5. Conclusion

This research developed an integrated decision-making framework combining the AHP with a stochastic cost assessment model to evaluate different TREES green building certification levels. The AHP method was used to prioritise sustainability criteria and cost aligned with the TREES rating system and GB cost stability. The stochastic model was then applied to define the uncertainty and variability of costs across certification options using Monte Carlo simulation. The results revealed that although higher certification levels such as Platinum achieve superior sustainability scores, they are also associated with higher initial investments and greater cost variability. In contrast, Silver demonstrated the optimal balance between sustainability performance, cost predictability, and financial risk. Additionally, the Silver certification level offers the shortest payback periods and lower cumulative cost uncertainty. By integrating qualitative prioritisation and quantitative cost simulation, this framework offers a more comprehensive and realistic approach to green building decision-making. It provides valuable guidance, cost-conscious decisions for GB developers, particularly in the context of Thailand's TREES certification system.

6. Limitations and Recommendations

This study is limited by the lack of research and data specific to the TREES certification system, particularly in relation to cost assessment. Unlike international frameworks such as LEED or BREEAM, TREES lacks comprehensive studies on cost-efficiency and investment performance. This limits the ability to benchmark for green building development in the Thai context.

Future research should explore more real-world data on TREES-certified buildings, especially focusing on cost breakdowns, long-term savings, and how different building types perform financially. It would also be useful to compare TREES with other international GB systems to better understand in terms of cost-efficiency. Finally, the decision-making tools could help designers and developers make more informed choices when planning sustainable buildings, especially in Thailand.

References

1. WorldGreenBuildingCouncil. *Bringing embodied carbon upfront*. 2025; Available from: https://worldgbc.org/climate-action/embodied-carbon/.
2. Fishbein, B.K., *Building for the future: strategies to reduce construction and demolition waste in municipal projects*. 1998: INFORM, Incorporated.
3. Osmani, M., *Chapter 15 - Construction Waste*, in *Waste*, T.M. Letcher and D.A. Vallero, Editors. 2011, Academic Press: Boston. p. 207-218.
4. Kibert, C.J., *Sustainable construction: green building design and delivery*. 2016: John Wiley & Sons.
5. Korkmaz, S., D. Riley, and M. Horman, *Piloting evaluation metrics for sustainable high-performance building project delivery.* Journal of construction engineering and management, 2010. **136**(8): p. 877-885.
6. Awadh, O., *Sustainability and green building rating systems: LEED, BREEAM, GSAS and Estidama critical analysis.* Journal of Building Engineering, 2017. **11**: p. 25-29.
7. ThaiGreenBuildingInstitute, *Thai's Rating of Energy and Environmental Sustainability for New Construction and Major Renovation and Core and Shell Building*. Vol. 1.1. 2017, Bangkok.
8. Robichaud, L.B. and V.S. Anantatmula, *Greening project management practices for sustainable construction.* Journal of management in engineering, 2011. **27**(1): p. 48-57.
9. Raouf, A.M. and S.G. Al-Ghamdi, *Building information modelling and green buildings: challenges and opportunities.* Architectural Engineering and Design Management, 2019. **15**(1): p. 1-28.
10. Feng, H., et al., *Uncertainties in whole-building life cycle assessment: A systematic review.* Journal of Building Engineering, 2022. **50**: p. 104191.
11. Streimikiene, D., et al., *Uncertain multi-criteria sustainability assessment of green building insulation materials.* Energy and Buildings, 2020. **219**: p. 110021.
12. Gultekin, P., et al., *Process indicators to track effectiveness of high-performance green building projects.* Journal of construction engineering and management, 2013. **139**(12): p. A4013005.
13. Dwaikat, L.N. and K.N. Ali, *Green buildings life cycle cost analysis and life cycle budget development: Practical applications.* Journal of Building Engineering, 2018. **18**: p. 303-311.
14. Arun, C., et al. *Cost overrun assessment for green construction project*. in *Proceedings of the World Construction Conference*. 2012.
15. Rehm, M. and R. Ade, *Construction costs comparison between 'green'and conventional office buildings.* Building Research & Information, 2013. **41**(2): p. 198-208.
16. Li, Y., et al., *Exploring green building certification credit selection: A model based on explainable machine learning.* Journal of Building Engineering, 2024. **95**: p. 110279.
17. Altomonte, S., et al., *Indoor environmental quality and occupant satisfaction in green-certified buildings.* Building Research & Information, 2019. **47**(3): p. 255-274.

18. Choi, J.O., et al., *LEED credit review system and optimization model for pursuing LEED certification.* Sustainability, 2015. **7**(10): p. 13351-13377.
19. Wu, P., et al., *A comprehensive analysis of the credits obtained by LEED 2009 certified green buildings.* Renewable and Sustainable Energy Reviews, 2017. **68**: p. 370-379.
20. Elbeltagi, E., et al., *Visualized strategy for predicting buildings energy consumption during early design stage using parametric analysis.* Journal of Building Engineering, 2017. **13**: p. 127-136.
21. Dangana, Z., W. Pan, and S. Goodhew, *A decision making system for selecting sustainable technologies for retail buildings.* Energy and the Built Environment Proceedings, 2013.
22. Linkov, I. and E. Moberg, Multi-criteria decision analysis: environmental applications and case studies. 2011: CRC Press.
23. Tatari, O. and M. Kucukvar, Cost premium prediction of certified green buildings: A neural network approach. Building and Environment, 2011. 46(5): p. 1081-1086.
24. Alshamrani, O.S. and A. Alshibani, Automated decision support system for selecting the envelope and structural systems for educational facilities. Building and Environment, 2020. 181: p. 106993.
25. Shen, W., et al., Understanding the green technical capabilities and barriers to green buildings in developing countries: A case study of Thailand. Sustainability, 2018. 10(10): p. 3585.
26. Jato-Espino, D., et al., A review of application of multi-criteria decision making methods in construction. Automation in construction, 2014. 45: p. 151-162.
27. Darko, A., et al., Review of application of analytic hierarchy process (AHP) in construction. International journal of construction management, 2019. 19(5): p. 436-452.
28. AlAwam, Y.S. and O.S. Alshamrani, Initial cost assessment stochastic model for green buildings based on LEED score. Energy and Buildings, 2021. 245: p. 111045.
29. Illankoon, I.M.C.S., et al., Key credit criteria among international green building rating tools. Journal of Cleaner Production, 2017. 164: p. 209-220.
30. WorldGreenBuildingCouncil. World Green Building Council calls on EU policymakers to take decisive action on the built environment. 2025; Available from: https://worldgbc.org/.
31. Azhar, S., et al., Building information modeling for sustainable design and LEED® rating analysis. Automation in construction, 2011. 20(2): p. 217-224.
32. Sun, D., W. Shao, and J. Li, Incremental cost investigation of green building in China. Construction Science and Technology, 2009. 6: p. 34-37.
33. Chen, Z., Current situation of green building label projects and their technical application in China. Journal of Central South University (Science and Technology), 2012. 43: p. 283-289.
34. Nalewaik, A. and V. Venters, Cost benefits of building green. IEEE Engineering Management Review, 2010. 38(2): p. 77-87.
35. Nicolow, J. Measuring The Cost To Become LEED Certified. 2025 [cited 1st March 2025; Available from: https://www.facilitiesnet.com/green/article/Measuring-The-Cost-To-Become-LEED-Certified--10057?utm_source=chatgpt.com.
36. Uğur, L.O. and N. Leblebici, An examination of the LEED green building certification system in terms of construction costs. Renewable and Sustainable Energy Reviews, 2018. 81: p. 1476-1483.
37. Kats, G., et al., The costs and financial benefits of green buildings. A report to California's sustainable building task force, 2003. 134.
38. Luchkina, V. Sustainable model for the implementation of a green building project. in E3S Web of Conferences. 2019. EDP Sciences.