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Research Paper

LEED building project management in Thailand

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ABSTRACT

Green construction management practices have become a necessity in the modern construction industry. However, the ever-growing demand for green buildings in Thailand necessitates the appropriate green project management systems which are distinct from those involved in managing a conventional project. LEED certification is the most acceptable green rating system. In this research paper, seven LEED building projects in Thailand are investigated to generate information concerning the common processes inherent in green project management. Forty stakeholders, including project owners, designers, contractors, LEED consultants and facility managers associated with the projects, were interviewed. The results shown in terms of recommended management guidelines for developing LEED projects in Thailand comprising four phases. These consist of conceptual and feasibility, design, construction and project delivery phases. Our proposed guidelines can potentially benefit future green project developments in order to enhance global sustainability. This paper suggests the guideline for project management with LEED project in Thailand which is appropriate to utilize further in developing context.

1. Introduction

Globally, natural resources are consumed everyday causing considerable environmental problems. The construction industry represents a major contributor to such a dire situation. The construction, use and demolition of buildings generates substantial social and economic benefit for society, but may also incur serious negative impacts, in particular on the environment (UNEP, 2007). Green building stands as an alternative. It is more efficient, costs less to operate, increases productivity, and contributes to healthier living and working environments for occupants (Kubba, 2010)]. Green buildings consume 35-40% less energy than conventional buildings (The Economist, 2004). Project management approaches for overseeing green building projects are different from conventional ventures (Lippaiová and Sebestyen, 2013). Hwang and Ng (2013) revealed ten challenges facing green construction projects in Singapore. They are (1) the longer time required during the pre-construction process; (2) difficulties in the selection of subcontractors who provide green construction services; (3) uncertainty concerning green materials and equipment; (4) high cost of green materials and equipment; (5) increased meetings and coordination required with green consultants and engineers; (6) more frequent alterations and variations with designs during the construction process; (7) difficulties in comprehending the green specifications in the contract details; (8) unforeseen circumstances in

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executing green projects; (9) planning of non-traditional construction sequences; and (10) planning of different construction techniques. Further critical factors experienced by green construction projects in China concern additional costs, incremental time, and the limited availability of green suppliers and information (Shi et al., 2013). Robichaud and Anantatmula (2011) gave an alternative approach when pursuing green project management strategies. This involves setting goals before initiating design and construction, integrating project teams, designing under a whole team approach, using bonuses and rewards in contracting, and training and communicating throughout the whole construction period. In implementing LEED construction projects, Bayraktar and Owens (2010) suggest guidelines as shown in **Fig. 1**. Major barriers in certifying green buildings in Turkey were found to involve the unavailability of approved materials, poor design of buildings, and difficulties with documentation processes (Aktas and Ozorhon, 2015). However, the management of green construction projects in Thailand is still in its infancy. There were approximately 27 new construction and major renovations (NC) and Core and Shell (CS) LEED buildings in Thailand as of September 2016 (USGBC, 2016). Official architectural and engineering guidelines concerning managing green construction projects in Thailand remain minimal and unrealised. Therefore, the objective of this research is to study current international project management processes in order to recommend guidlines for implementing LEED projects in Thailand. In addition, seven LEED projects are analysed in order to reveal common practices in implementation processes.

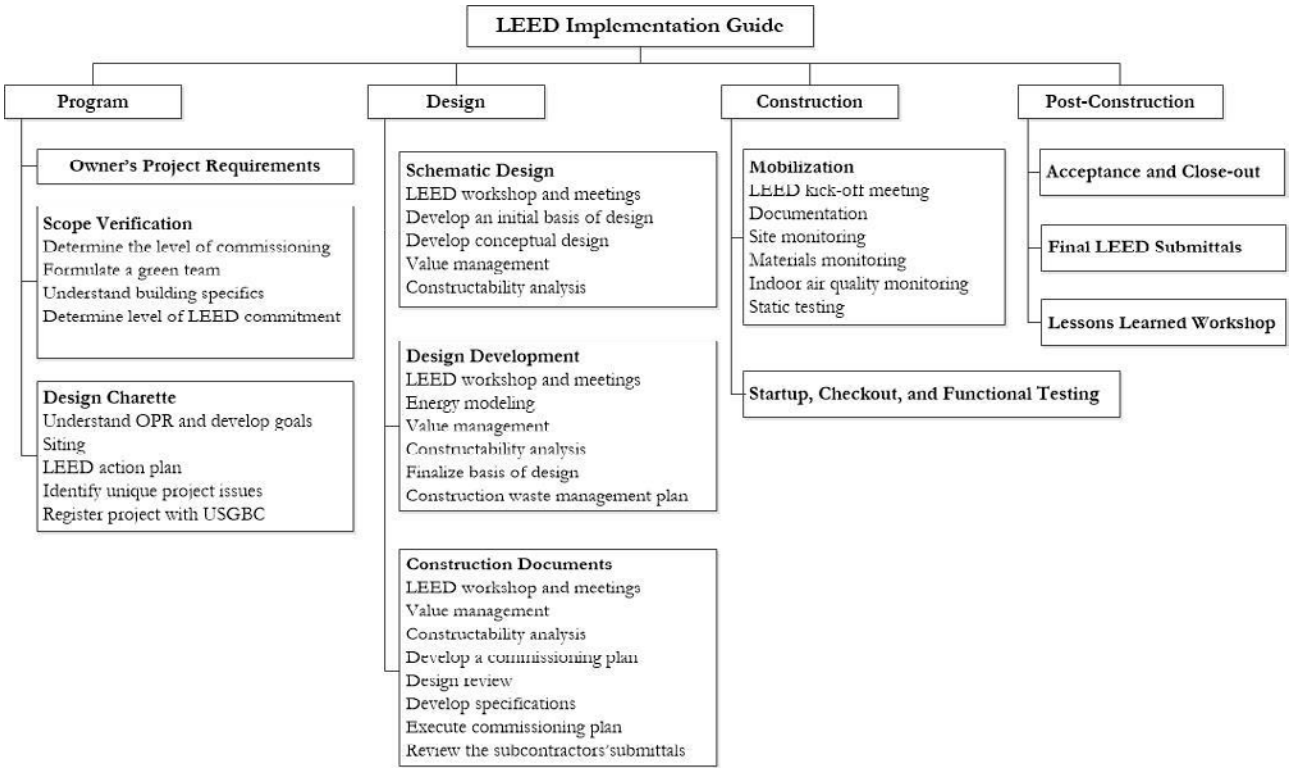

Fig. 1. Framework of the LEED Implementation Guide (Bayraktar, and Owens, 2010).

2. Research Methodology

In expediting this research we reviewed the literature regarding both LEED for new construction and major renovations (USGBC, 2009a) and LEED for Core and Shell (USGBC, 2009b) to create a questionnaire allowing in-depth interviews with multidimensional stakeholders. The seven projects selected comprised two LEED-NC Platinum ventures, one LEED-NC gold, one LEED-NC Silver, two LEED-CS platinum, and one LEED-CS gold. Forty representatives from the seven projects were interviewed, composed of five project owners, 12 A/E designers, five contractors, 13 LEED consultants, and five facility managers. Details of the interviewees are given in **Table 1**, while **Table 2** reveals basic background information concerning the seven projects under investigation.

Table 1. Interviewee data (40 persons).

Profile	Project Owners (n=5)	Architectural/ Engineering Designers (n=12)	Contractors (n=5)	LEED Consultants (n=13)	Facility Managers (n=5)
Education					
▪Bachelor	-	5	2	4	3
▪Master and above	5	7	3	9	2
Professional Experience					
▪Less than 10 yrs	-	1	3	8	3
▪11-20 yrs	1	8	1	2	2
▪More than 20 yrs	4	3	1	3	-
Business Function					
▪Senior Executives (Director, Chief Officer)	3	1	1	-	-
▪Middle Executives (Manager, Senior)	2	6	2	3	5
▪Operators	-	5	2	10	-

Table 2. Background Information for Seven Projects Investigated in this Research.

Project Reference	Floor Area (sq.m)	Submission Options	Design Duration (months)	Design Review Duration with LEED Accreditation (months)	Construction Duration (months)	Construction Review Duration with LEED Accreditation (months)	Total Project Duration (months)
1. LEED-NC Platinum certified building	5,000	Split review	12	6	18	6	42
2. LEED-NC Platinum certified building	400	Split review	13	13	7	4	37
3. LEED-NC Gold certified building	7,175	Combined review	12	-	24	7	43
4. LEED-NC Silver certified building	1,702	Combined review	8	-	14	4.50	26.50
5. LEED-CS Platinum certified building	304,000	Split review	27	18	36	9	66
6. LEED-CS Platinum certified building	46,251	Split review	13	4.5	27	1	48.50
7. LEED-CS Gold certified building	83,785	Split review	4	1	24	1.5	36

Table 3. Content Analysis of Phase 1 Activity from 40 Interview Respondents involved in Seven Projects.

Research Questions	Analysis				
	Project Owners (n=5)	Architectural/ Engineering Designers (n=12)	Contractors (n=5)	LEED Consultants (n=13)	Facility Managers (n=5)
Phase I: Conceptual & Feasibility Phase					
1. In your point of view, what is the purpose that the owner develops a LEED project?	Project Owners (3/5) CSR	A/E Designers (8/12) CSR	Contractors (2/5) CSR	LEED Consultants (9/13) CSR	N/A
2. What is the most important thing that the owner should know and be able to explain to others for a successful LEED building project at the earlier stage?	Project Owners (2/5) Owner's Project Requirements (OPR)	A/E Designers (8/12) OPR and Owner's Commitments	Contractors (2/5) BOD (Basis of Design) that are developed from OPR	LEED Consultants (10/13) - Owner's Commitments, OPR - Components of OPR	N/A
3. Please explain a process of design charrette you adopted in your project management?	Project Owners (5/5) - Design charrette - Identified in brainstorm session (2/5)	A/E Designers (10/12) Did not define the terms of design charrette	Contractors (4/5) - Design charrette can be operated in parallel due to time limitations - Identified in brainstorm session (2/5)	LEED Consultants (10/13) Did not define the terms of design charrette	N/A

3. Analysis

Interview responses were analysed using a content analysis methodology (Stemler, 2001) and summarized according to research questions, as shown in **Tables 3** to **6**. Each table contains the research results inform each of four different phases. The four phases of the project management of LEED buildings in this research comprised conceptual and feasibility study, design, construction, and project delivery. The research

questions in Phase I, Phase II, and Phase III mainly concern project owners, A/E designers, contractors, and LEED consultants. The responses of facility managers are not applicable in **Tables 3** to **5**.

The questions were divided into four phases comprising conceptual and feasibility, design, construction, and project delivery. There are between two and five questions each phase, as shown in column 1 of **Tables 3**.-**6**. Content analysis techniques are used in the analysis by making replicable and valid inferences from the data to their context (Krippendorff, 2012) .The context results from the interviews may be summarized as follows.

Phase I: Conceptual and Feasibility Study Phase

Three conclusive findings were found in this phase. They are related to project motivation, Owner's Project Requirements, and design charrette.

1. LEED Building Project Motivation in Thailand

Financial incentives, such as tax credits, and incentives encouraging greenhouse gas emission reductions remain lacking in Thailand. The objectives of LEED projects in Thailand mainly focus on supporting corporate social responsibility initiatives to bolster their public image, as revealed in responses to Question 1 in **Table 3**. Public companies, such as PTT Public Company Limited, Kasikorn Bank, and Siam Cement Group, mentioned corporate images considerations as their main reasons for seeking and earning green building certification.

Table 4. Content Analysis of Phase 2 Activity from 40 Interview Respondents involved in Seven Projects.

Research Questions	Analysis				
	Project Owners (n=5)	Architectural/ Engineering Designers (n=12)	Contractors (n=5)	LEED Consultants (n=13)	Facility Managers (n=5)
Phase II: Design Phase	Project Owners	A/E Designers	Contractors (3/5)	LEED Consultants	
1. What do you do during initiating the design process and what tools are used in this phase?	(5/5) LEED credit scorecard	(12/12) LEED credit scorecard	LEED credit scorecard	(13/13) LEED credit scorecard, included three-sub components of the scorecard (4/13)	N/A
2. What documents do you use during this phase, which are different from those employed when designing a typical building?	Project Owners (5/5) - Calculation documents - Commissioning documents - Technical specifications Materials Safety Data Sheets (MSDS), etc. Aligned with LEED credits and approved material related documents	A/E Designers (9/12) - LEED credit scorecard and project status updating documents - Calculation documents - Technical specifications (MSDS, Low VOCs) aligned with LEED credits and approved material related documents - Commissioning documents Documents need to be prepared in English, entailing 20% extra time (compared to the design of a conventional building).	Contractors (4/5) - Technical specifications regarding relevant materials and equipment with LEED credits	LEED Consultants (13/13) - Calculation documents - Commissioning documents - Bidding documents, such as TOR with LEED requirements - Technical specifications (MSDS, Low VOCs) aligned with LEED credits and approved material related documents Documents need to be prepared in English, entailing 20% extra time (compared to the design of a conventional building).	N/A
3. What kind of software do you use frequently during the design stage of LEED building projects?	Project Owners (3/5) Simulation software	A/E Designers (11/12) - Simulation software (commonly used and optionally used)	Contractors (4/5) Simulation software	LEED Consultants (11/13) - Simulation software (commonly used and optionally used)	N/A
4. Does a contractor participate in designing a green building?	Project Owners (3/5) No role of contractors in design phase	A/E Designers (12/12) No role of contractors in design phase, but suppliers or nominated subcontractor are found to be active in this phase.	Contractors (4/5) No role of contractors or subcontractors during design session, also mention the example of a project owner selecting a nominated subcontractor.	LEED Consultants (7/13) No role of contractors in design phase	N/A

Table 5. Content Analysis of Phase 3 Activity from 40 Interview Respondents involved in Seven Projects.

Research Questions	Analysis				
	Project Owners (n=5)	Architectural/ Engineering Designers (n=12)	Contractors (n=5)	LEED Consultants (n=13)	Facility Managers (n=5)
Phase III : Construction Phase 1. In your opinion, what is the role of LEED AP and LEED Administrator at this phase?	Project Owners (3/5) LEED AP has an important role in giving support advice and answering any enquiries from stakeholders, especially contractors.	A/E Designers (11/12) LEED AP is responsible for the coordination and approval of materials and equipment submission, including construction method statements.	Contractors (5/5) LEED AP has an important role in giving support advice and answering any enquiries from contractors.	LEED Consultants (13/13) LEED administrator is responsible for project documentation. There is one suggestion concerning acquiring a LEED AP in the contractor team.	N/A
2. If there is a LEED session meeting, what is the topic of the construction meeting?	Project Owners (3/5) It can be inserted into construction project meetings. To focus on project scope and details that are related to LEED credit requirements.	A/E Designers (11/12) Implemented tasks, ongoing activities and planned tasks related to LEED credit fulfillment.	Contractors (4/5) The highlight of this session meeting concerns implemented tasks, ongoing activities and planned tasks related to LEED credits.	LEED Consultants (11/13) The agenda included a) updated LEED credit scorecard b) follow-up implementation according to LEED requirements c) LEED online submittals Contractor responsibility regarding three LEED credits.	N/A
3. If there is a change order during the construction phase, how does it affect your construction process and LEED score.	Project Owners (0/5) No comment	A/E Designers (1/12) Material specification unmatched with LEED requirements. - Time delays - Cost escalation	Contractors (0/5) No comment	LEED Consultants (1/13) Initial design not suitable in terms of working function and utilization. - Impact score in one point - Changing working function	N/A
4. What are the contingency credits implemented during construction in order get the desired score?	Project Owners (0/5) No comment	A/E Designers (4/12) During construction, a reserved plan for credits compensation is needed to mitigate for uncertainty or unforseen circumstances.	Contractors (0/5) No comment	LEED Consultants (4/13) Dismissed during construction, the backup score can be definitely considered to reserve.	N/A
5. What training topics are important for a contractor to learn about before starting construction?	Project Owners (2/5) - Documentary process - Example templates	A/E Designers (6/12) According to LEED requirements clarification, process explanations, and question handling.	Contractors (3/5) Sub-contractors, and nominated sub-contractors should be trained on related topics.	LEED Consultants (8/13) - Documentary process - Example templates Specified LEED credit SSp1, IEQc3.1-3.2, and MRc2	N/A

Table 6. Content Analysis of Phase 4 Activity from 40 Interview Respondents involved in Seven Projects.

Research Questions	Analysis				
	Project Owners (n=5)	Architectural/ Engineering Designers (n=12)	Contractors (n=5)	LEED Consultants (n=13)	Facility Managers (n=5)
Phase IV : Delivery Phase 1. What are the differences in the commissioning process in LEED building projects in contrast with conventional buildings?	Project Owners (4/5) – OPR – BOD – Manual of commissioned systems	A/E Designers (10/12) Especially EAc3 (if chosen), it is required to review all design and related parameters. The commissioning process for LEED building includes prefunctional checklists and functional checklists with descriptions in detail.	Contractors (3/5) – OPR – BOD The commissioning and enhanced commissioning (EAc3) processes. These are different from the normal testing of conventional buildings.	LEED Consultants (11/13) – OPR – BOD – Manual of commissioned systems The commissioning process is different from the normal testing of conventional buildings.	Facility Managers (4/5) Similar to those derived from LEED consultants' answers. The commissioning process include photographing and reporting key parameters, such as luminous efficacy, ventilated wind speed, sound, ambient temperature, and humidity measurements. To align with technical standards, such as ASHRAE.
2. Please explain about the demonstrative practices in the LEED Credit Submittals Process, especially in Thailand context?	Project Owners (0/5) No comment	A/E Designers (3/12) LEED consultants submit preliminary designs in order to potentially earn each credit.	Contractors (0/5) No comment	LEED Consultants (6/13) In terms of the LEED credits submittal process, the submission of a split review is advantageous, descriptions in detail.	Facility Managers (0/5) No comment

2. Owner's Project Requirements (OPR)

OPR comprises the basic recommended components indicated in LEED reference guides. For a building to be classified as attaining LEED-NC platinum requirements it must meet several criteria, comprising 1) displaying evidence of its company's vision, 2) satisfying general requirements and features including environmental and sustainability goals, energy efficiency goals, IEQ requirements, equipment and system expectations, building occupants and operational and maintenance personnel expectations, 3) meeting commissioning process standards, 4) operating a satisfactory health and safety program, 5) fulfilling design team objectives, and 6) reviewing and evaluating project goals as per OPR

3. The Importance of the Design Charrette

Teamwork should be initiated and encouraged from the early phase of design onwards. The design charrette represents a team comprising A/E designers, project owners, and LEED consultants who examine the components of OPR and specify or designate possible LEED credits for a project during this phase. A project cost model can be roughly developed for different alternatives in terms of a conceptual and feasibility study. LEED score credits which are either costly or difficult to implement are neglected to enhance project feasibility. Finally, the total cost of preliminary design is estimated to allow the owner to make a decision concerning further developing comprising construction drawings. However, the design charrette can potentially be operated parallel to the design phase according to time limitations.

Phase II: Design Phase

The design phase consists of four elements. The associated tasks inherent in each element are described below.

1. Using LEED Credit Scorecard for Design Development

LEED credit scorecards were accepted as a consensus by all parties, as found in the first question in **Table 4**. They are used as a main tool within the design procedure by A/E designers and LEED consultants. A checklist for the LEED credit scorecard is prepared to link with the construction drawings to allow for the possibility

of gaining a LEED score. Additionally, the checklist is used to promote coordination and communication among all project stakeholders during the design phase.

LEED credit scorecards need to be filled in and updated on the LEED online submittal system. There are three types of LEED credit scorecard which are found in Thai green projects. They comprise yes, no, and maybe items.

(1) A Yes item corresponds to a credit which is found in all projects studied in this research. There are a total of 16 credits as follows:

- SSc1, SSc2, SSc4.3, SSc4.4, SSc7.1, and SSc7.2 refer to credits related to site selection, developing a project which is connected to the community and provides alternative transportation with low-emitting and fuel-efficient vehicles, parking capacity, and a reduced heat island effect.
- WEc2 and WEc3 are credits which involve innovative wastewater technologies, such as grey water recycling systems and the use of high-efficiency plumbing fixtures in order to reduce water usage.
- Two EA credits were found. They are EAc1 and EAc5. Energy performance should be optimized by using appropriate building envelopes and high efficiency lighting, together with HVAC systems. The installation of submetering to measure energy usage in buildings and the following up on energy consumption for at least one year after project occupancy is required.
- Waste handler subcontractors were hired by a main contractor to recycle and salvage construction waste materials. As a result, one credit is earned for MRc2.
- IEQc2, IEQc3.1, IEQc4.1, and IEQc4.2 represent credits found in all seven projects wherein air ventilation must stand at least thirty percent above minimum rates. They also necessitate the protection of HVAC systems by wrapping them with plastic sheeting to cover open grilles and ductwork, together with the installation of both temporary MERV 8 filters at return air grills and temporary partition walls to separate working areas with dust as standard practice during construction. M&E rooms are not allowed to act as store rooms during construction, which was previously common practice in Thailand. Gypsum boards need to be stored in dry places with packaging protection to prevent dampness. Low-emitting adhesives are required to be used in all projects with sealants, paints, and coating materials.
- SSc9 for LEED-CS projects were found in all CS projects studied in this research. It represents guidelines for tenants to implement in areas they are responsible for according to sustainable design tenets.

(2) An item classified as No refers to a credit which is not practiced across all seven projects found in this research. They comprise SSc3 brownfield redevelopment and MRc1.2 building reuse-maintain within existing interior nonstructural elements. Six projects in this research represent new building projects, while one project is a major renovation scheme. None of the seven projects are implemented within contaminated areas. With respect to the major renovation project, the existing roof and structural system are reused, while all existing external and internal walls are demolished.

(3) An item classified as Maybe refers to a practice which is implemented in certain projects at an incidence varying from one to six. Some credits are viewed as offering high potential credit by designers. The following 12 credits are found for five to six projects within the total of seven ventures. These are shown as a histogram in **Fig. 2**.

- SSc4.1, SSc4.2, SSc5.2, and SSc6.1 refer to credits providing alternative public transportation by showing walking paths from the main entrance of a building to a bus stop within 400 meters, and/or a subway station within 800 meters. Moreover, they entail arranging bicycle racks and/or storage spaces with shower and changing facilities, maximizing open space areas, and controlling stormwater runoff in order to not exceed predevelopment runoff rates. Six projects were found to have earned these credits.
- WEc1 credit involves increased water efficiency in landscaping areas. Five projects were able to reduce potable water consumption for irrigation by 50% and/or 100% by planting native plant species, capturing rainwater and recycling wastewater. One LEED platinum project involved the construction of a wetland system promoting water efficiency in landscape usage.
- EAc3 and EAc4 refer to credits that are involved with enhanced commissioning and refrigerant management. Six projects were found to have hired CxA to lead, execute, review, and oversee a design review and submit this review together with system manuals. Activities related to refrigerant management include preventing leakage of CFCs, HCFCs, or Halons into the atmosphere and prohibiting the use of HCFCs or Halons in fire suppression systems.
- MRc4 and MRc5 are credits that are involved with selecting products and materials. The materials used in green building projects must contain

recycled content and be manufactured within Thailand. Five projects were found to be using documents showing the percentage of post- and pre-consumer material, and the distances from raw material sources to construction sites.

- IEQc1 involves the installing of CO_2 monitoring sensors in densely occupied areas. They are designed to alert building operators when carbon dioxide levels differentiate from their optimal design value by 10% or higher via either a BAS alarm or audible alert. However, in non-densely occupied areas air velocity sensor will be used to measure outdoor air intake flow to ensure it is in accordance with design values. Otherwise, sensors will cause alarms to be raised or operate fresh air intake fans.
- IEQc7.1 and IEQc8.2 represent credits related to thermal comfort design and daylight and view specifications. Six projects were found to have earned these credits. They involve designing HVAC systems for air conditioned areas in compliance with ASHRAE standard. Six projects included these measures within their design specifications, incorporating views through glazing for more than 90% of regularly occupied floor areas with direct lines of sight.

The following seven credits were found in three to four projects, which are sorted by highest frequency. These can viewed as potential credits.

- SSc5.1 and SSc6.2 were present in four projects. They all apply SSc5.1 case 2 which denotes previously developed areas or graded sites. Designers have to restore or protect a minimum of 50% of the site, excluding the building footprint, or 20% of the total site area. The building footprint area has to be minimized to help restore or protect ecosystems and promote biodiversity through native plants that require minimal or no irrigation, or require active maintenance. With regard to SSc6.2, three projects were found to have installed underground rain water collection tanks. Meanwhile, one LEED platinum project installed a natural treatment systems utilizing a sand filter infiltration basin in the treatment stormwater runoff for 90% of the average annual rainfall in addition to reusing water within landscape areas.
- IEQc4.3 credits were revealed in four of the projects. They uniformally applied for Option 1, which entails floor coverings utilizing natural stone tiles, granite, terrazzo, carpets, and linoleum tiles. Adhesives used with the floor coverings were required to have a low VOC content involving a limit less than specified at 50 g/L.
- SSc8 was found in three of the projects. These ventures installed automatic lighting switches to turn off lighting fixtures which have a direct line of sight to building openings at a rate of greater than 50% between 11 p.m. and 5 a.m. daily. With respect to exterior lighting, two projects were found to employ LZ2 and one project LZ3, which are designed for primary residential zones and commercial or high density residential areas, respectively. In these cases, the total actual light power density for tradable and non-tradable surfaces must be less than or equal to the base site allowance. Moreover, the sum of the total lumens of all fixtures on site must be less than 2% and 5% for LZ2 and LZ3, respectively.
- The credit for IEQc3.2 awarded for three projects. All of these selected the Option 1 Path 1 pathway which involves flushing out a whole building with fresh outdoor air after construction is completed at a rate of 14,000 CFM/sq.ft. IEQc6.1 was also found present in three projects. This may be divided into two options which are individual and shared multi-occupant controls. Two in three projects have individual workspaces and are designed to use task lighting for at least 90% of the building occupants. For shared multi-occupant controls, two in three projects use multi-zone lighting control systems, dimmers, and individual switches. However, one LEED-NC platinum project, which is a library, installed both daylight and occupancy sensors in order to earn this credit.
- The IEQc8.1 credit was earned in three projects. These projects used Option 2, which involves a prescriptive explanation using an Excel program. They demonstrated that buildings can achieve daylight in at least 75% of all regularly occupied spaces in order to earn this credit. This necessitated prescriptive calculations showing that the product of visible light transmittance (VLT) and window-to-floor area ratio (WFR) of the regularly occupied spaces lies between 0.15 and 0.18.

The following can be refered to as possible credits and were found in one or two of the projects.

- EAc2 was found to be submitted in order to earn credits in the case of two projects. They installed solar photovoltaic cells on rooftops and were able to save annual building electricity at rates of 420,000 kWh and 99,000 kWh, respectively. The two projects earned one credit from EAc2.
- EAc6 was earned by two projects who bought green power contracts, both Green-e certified, for durations of at least two years enabling them to

provide at least 35% of their building electricity through these means.

- IEQc5 credits were found in two projects which minimized and controled all captured dirt, particulates, hazardous gases and chemical pollutants. Both projects installed three systems in their buildings. First, floor entryway systems were introduced at main entrances to trap any occupant-borne contaminants entering the buildings. Second, copying and printing rooms in buildings were designed and constructed to provide negative air pressure conditions. MERV13 filters were also installed in air handling units for both return and outside air intake before channelling it to all regularly occupied areas.
- The category of IEQc7.2 was recorded in two LEED-NC projects. Both projects implemented thermal comfort surveys to monitor temperature variations, humidity, and drafts.
- A MRc1.1 credit was earned in one LEED platinum project. It reused main building structures, comprising structural floors, frames and roof decking. This project was able to reuse 95% of main building structures and earned three points.
- A MRc3 credit was achieved in one LEED platinum project. It involved reusing salvaged building materials and products. This LEED platinum project reused old hardwood doors, hardwood eaves, and wood ceilings from other buildings and was able to reuse materials for a sustainable criteria at a value of 10.20% of total material costs, enabling it to earn two points
- A MRc6 credit was found in one LEED platinum project involving rapidly renewable materials. A 100% cotton curtain was used with a value of 2.92% of the total cost of all building materials. Thus, this project earned one point.
- A MRc7 credit was earned in one LEED platinum project which used FSC-certified wooden doors for more than 50% of the total cost of wood-based materials and products, earning one point.
- Finally, an IEQc4.4 credit was found in one LEED platinum project wherein composite wood and agrifiber products which had no urea-formaldehyde resins were used in the built-in furniture fitted. All the furniture employed greenlam laminates and green board products. They accounted for more than 50% of the total cost of wood-based materials and, consequently, earned one point.

Items categorized as Maybe varied, being found in between one and six projects. Their implementation was based on project characteristics and owner requirements. After studying the possible LEED credit scorecards found in Thailand, the next section will reveal details of the documents which must be prepared by project management teams before being submitting to LEED.

2. Extending Design Process Duration due to Abundance of Related Documentation

Table 7. reveals details of the related documentation required in items 1 to 6 in the design phase which are not commonly found in conventional projects. The documents need to be prepared in English. A/E designers and LEED consultants recommend sparing 20% more time than is allocated in conventional building projects.

Table 7. Related Documentation in the Design Phase of LEED Projects.

Item	Description	Responsible Function
1	Calculation documents and compiled calculation items related to standards of operation, such as ASHRAE 90.1 or ASHRAE 62.1	Engineering designers and specialists
2	Commissioning documents	A/E designers coordinated with CxA
3	Bidding documents, such as TOR with LEED requirements.	Project owners, LEED consultants and construction managers
4	Document related to technical specifications to present relevant materials & equipment with LEED credits, such as supplier product information sheets, Materials Safety Data Sheets (MSDS), etc.	Suppliers
5	Approval material related documents with technical specifications in item 4, such as the selection of paint colors with Low VOCs etc.	A/E designers coordinated with LEED consultants
6	LEED credit scorecards and project status updating documents. Related documents with the possibility of extra LEED scores.	LEED consultant teams and A/E designers

3. Software used during the Design Stage of LEED Projects in Thailand

Nowadays, there are various software packages that support LEED building design, as shown in **Table 8**. Softwares items 1-3 are commonly used and were found in every project that earned credits, whereas items 4-5 are optionally used and found in only one to two projects.

Table 8. Software Used during the Design Stage of LEED Projects.

Item	Description	LEED Credits	Software
1	Design software for whole building projects, such as eQuest, Visual DOE, EnergyPlus etc.	EAp2, EAc1 and EAc5	Energy Simulation
2	Design software to evaluate light factors, such as Dialux etc.	IEQc8.1 and SSc8	Daylight Simulation
3	Design software to predict run-off conditions into site locations.	SSc6.1	Water Runoff and Storm Simulation
4	Design software to calculate the installation of photovoltaic systems, such as PVSyst software etc.	EAc2	Photovoltaic software (PVSyst)
5	Design software to design the location of ventilation fans and the CFM size of fans	IEQp1, IEQc2	Computational Fluid Dynamics (CFD) software

4. The Role of Contractors in the Design Phase

In Thailand, contractors do not have the opportunity of participating during the design phase of projects. However, suppliers or nominated subcontractors do help designers prepare documents related to the materials and equipment used in projects. In one example, a project owner selected a nominated subcontractor with experience in two LEED building projects to supply, install and commission HVAC systems.

Phase III: Construction Phase

The construction phase consists of four constituents which are outlined below.

1. The Role of LEED AP and LEED Administrators in Certified LEED Projects

LEED accredited professional (LEED AP) refers to an appointed person from the USGBC appointed to help a project management team. Hiring a LEED AP as member of a project team allows a project to gain one credit in line with IDc2. In Thailand, LEED APs are responsible for monitoring developments from the conceptual through to the commissioning phase and have an important role in giving advice and answering enquiries from stakeholders, especially contractors. Their duties involve approving construction materials, installing equipment, and deciding on methods of statement. One suggestion from a LEED consultant of a LEED platinum building project was to acquire a contractor who has a LEED AP in his team to enhance the contractor's competency in completing a successful LEED project. Another important person is a LEED administrator. They are responsible for LEED project documentation, with duties including collecting and disseminating documentation to all parties and to Green Building Certification Institutes (GBCI).

2. Important Issues in LEED Session Meetings

The arrangement of LEED session meetings during construction periods are important and can be added to construction project meetings. These meetings concentrate on implemented tasks, ongoing activities, and planned tasks related to LEED credit fulfillment. The tasks focus on project scope and details. The agenda of sessions include a) updating LEED credit scorecards b) following up on implementation according to LEED requirements c) submitting data documents via LEED online submittal channels regarding materials and equipment approvals. Normally, contractors need to have three responsibilities specified in a contract document in order to earn LEED credits, as shown in **Table 9**.

Table 9. LEED Credits Implemented by Contractors.

Item	Description	LEED Credits
1	Construction activity pollution prevention	SSp1
2	Construction indoor air quality management plan during construction and before occupancy	IEQc 3.1-3.2
3	Construction waste management	MRc 2

3. Related LEED Credits Change Order during the Construction Phase

Two change orders were found in this study which impacted on LEED scores.

(1) Initial design not suitable for working function and utilization. In one LEED-NC platinum certified building, a LEED consultant mentioned that "First we designed a bicycle storage and a changing rooms for SSc4.2 in dimension 4.50x2.50 m. outside the main building. Then we found that the initial design was not suitable for library business have a changing room since it require extra maintenance. So our project team abandoned this credit which has one point." After construction was completed, the bicycle storage and changing room were altered to become a storeroom and parking lot, respectively.

(2) Material specification unmatched with LEED requirement. Two projects were found related to this scenario. In one LEED-NC platinum certified building, an A/E designer said that "We didn't get the score on IEQc4.4 or low-emitting materials-composite wood and agrifiber products that we initially planned." One supplier could not provide a MSDS showing that no urea formaldehyde was present in the installed laminated wood floors. In another LEED-NC platinum certified building, approval documents for silicone sealants and coatings were submitted late by a contractor. The contractor should have coordinated with suppliers for all of the materials listed in IEQc4.1 and IEQc 4.2 early in the project and prepared the owner's approval. This incident resulted in a two month delay by the contractor. The owner and contractor adjusted the construction plan by purchasing alternate materials, resulting in construction cost escalation. Since the silicone sealants and coatings which matched LEED specification were scarce in the Thai market, material costs related to sealants and coatings doubled in this case.

4. The Involvement of Contingency Credits

Usually, project credits will be allocated according to LEED credit scorecards. Yet, several reasons may cause changes in LEED projects during construction. A backup or reserve plan for credit compensation is needed to

mitigate such uncertainty. In Thailand, data for IEQc4.1-4.4 is not commonly available. For example, if MSDS for Low VOCs product is unavailable, a contingency credit shall be prepared. Two contingency credits were found in this research, EAc6 and IDc1. Two LEED platinum certified buildings purchased EAc6 credits from the center for resource solutions' green-e energy inititiative in order to attain two points from the credit. The IDc1 or innovation in design can be added later for design innovations, such as education booth exhibitions and chemical-free maintenance programs. In this research, two LEED platinum certified buildings used IDc1 as their contingency credits.

5. Training Sessions for Contractors

General contractors, sub-contractors, and nominated sub-contractors should be trained according to LEED requirements, as shown in **Table 10**. The training can be conducted at a kick-off site meeting. LEED consultant normally conduct hands-on training focusing on requirement clarification, process explanation, and question handling. LEED consultants explain documentary processes and prepare example templates concerning related topics for contractors. After meetings, contractors prepare documents and train their workforce on all topics highlighted in **Table 10**. A LEED consultant monitors and controls practices throughout projects.

Table 10. Training Topics for Contractors in LEED projects.

Item	Description	LEED Credits
1	ECS Plan (Soil Erosion and Sedimentation Control Plan) for Examples (1) Wheel wash basin installation (2) Hazardous waste management (3) Sediment control using earth dikes, silt fencing and sand bag installation for drainage pipe systems in onsite work. (All documentation and evidence should be recorded and reported.)	SSp1
2	The recommended Design Approaches of the Sheet Metal and Air Conditioning National Contractors Association (SMACNA) IAQ Guideline for Occupied Building under construction for example: (1) HVAC Protection during construction (2) Source Control during construction (3) Pathway Interruption during construction (4) Housekeeping during construction (5) Scheduling Management for information sessions on high risk activities regarding pollutants, off peak or non-occupancy phases and arranging for flush-out processes.	IEQc3.1-3.2
3	TOR specify constructors being involved in managing construction waste, such as dealing with the rubble of light weight bricks, metal scrap/remnants, landfill waste or divert specified overall quantity (volume or weight)	MRc 2

Phase IV: Project Delivery Phase

The delivery phase, or post-construction phase after finishing construction, consists of two guidelines recommended in this research. They are outlined below.

1. Commissioning Process

During the commissioning process all LEED building practices have to be performed according to the owner's project requirements, the basis of design, and follow the manual of commissioned systems, which are different from those involved in the normal testing of conventional buildings. In particular, when following EAc3 or the enhanced commissioning process, it is required to review design and related design parameters. The commissioning process for LEED building includes both prefunctional and functional checklists. Prefunctional checklists are submitted for approval, subject to an attached list of outstanding tasks to be completed as part of the startup and initial checkout process, preparatory to functional testing. Functional checklists will evaluate the functions of all equipment; examining whether working parameters are aligned with standards such as ASHRAE. The Commissioning Authority (CxA) will monitor whether functional performance is tested and the system manual is followed before commissioning a report. In particular, the CxA has the role of reviewing building operations eight to ten months after final project completion. The commissioning process includes photographing and reporting key parameters, such as luminous efficacy, ventilated wind speed, sound, ambient temperature, and humidity during daylight, lighting, and the performance of HVAC systems.

2. LEED Credits Submittal Process

LEED consultants have to submit construction documents, drawings, and the LEED credit templates involved in the LEED certification process to the GBCI. In this process, the consultant has two options First, a split review process which involves both a review after completion of the construction documents and after construction is substantially completed. Second, a standard review process which comprises a one-time review of both design and construction after substantial completion of the construction phase. From our interviews, three A/E designers and six LEED consultants suggested submitting to the split review process in order to better ensure success in earning LEED certification. Initially, LEED consultants should submit preliminary designs to potentially earn each credit. If a credit is denied, a LEED consultant has a chance to correct construction drawings or related documents in order to earn the desired LEED credit. There are both advantages and disadvantages inherent in each of the two options for LEED submittals, as shown in **Table 11**.

In this research, we also referred to the time frames of each of the seven projects and mentioned that the

LEED certification process merges the conventional design and construction processes, as shown in **Table 2**. However, five projects suggested submitting via the split review process. The exceptions to this involve the third and fourth projects in the above table which submitted using the option of a design and construction combined review process. However, a LEED consultant mentioned that the "Split review process suits high level award, large and complicated projects with high investment, whereas the standard review process is preferable for small projects with a lesser degree of award, such as those at the certified or silver level." Finally, the details of LEED building project management in Thailand are collated and shown in **Fig. 3**.

Table 11. Advantages and Disadvantages of the Two Options in the LEED Submittal Process.

Options	Advantages	Disadvantages
Split Review Process	- Preliminary design review allows the LEED consultant and team to get a chance to correct construction drawings or related documents in order to earn LEED credits denied at an earlier time. - Compliance with potential earning of each credit allows LEED consultant and team opportunities to attempt to gain additional points, especially during construction, if they prefer the upper level of LEED certification.	- Two times concerning LEED credit submittal process, first time after completing construction documents, and the second time after construction is substantially complete. - Wastes time and costs
Standard Review Process	- Just one time concerning LEED credits submittals process, one final review after substantial completion in the construction phase. - Saves time and costs	- LEED consultant and team have to wait until the end of construction or substantial project completion. - It is risky, LEED consultant and team have no chance to correct construction drawings in order to earn LEED credits if a credit submittal is denied.

4. Conclusions and Discussion

This research into the practice of green building project management in Thailand can be concluded by offering some guidelines for future ventures. In the conceptual and feasibility study phase, the motivation in developing green buildings differs from practices in the US, wherein local government provides permits and financial incentives (Robichaud and Anantatmula, 2011). In Thailand, matters connected to a company's public image drive the development of green building projects, which was conformed by Aktas and Ozorhon (2015). An owner's project requirements are normally used within green building project management starting from the conceptual phase through to the delivery process. They serve along with the basis of design in evaluating a contractor's project delivery. This is also confirmed by the study of Bayraktar and Owens (2010).Design charrette may not be formally implemented. However, key stakeholders including A/E designers, project owners, and LEED consultants work collaborately in developing the final design as is the case when working in traditional building projects. External stakeholders, such as surrounding property owners and other community representatives, are not included in this phase, as suggested by Robichaud and Anantatmula (2011). In the design phase, the use of a LEED credit scorecard is a common practice. In this research, LEED credit scorecards can be classified into three types, comprising Yes, No, and Maybe responses, as shown in **Fig. 2**. Yes items were found in connection with 16 credits which can be related to promoting an appropriate site development, minimizing the impact of microclimate change, promoting efficient water usage, optimizing energy performance and consumption, and higher outdoor air ventilation rates.

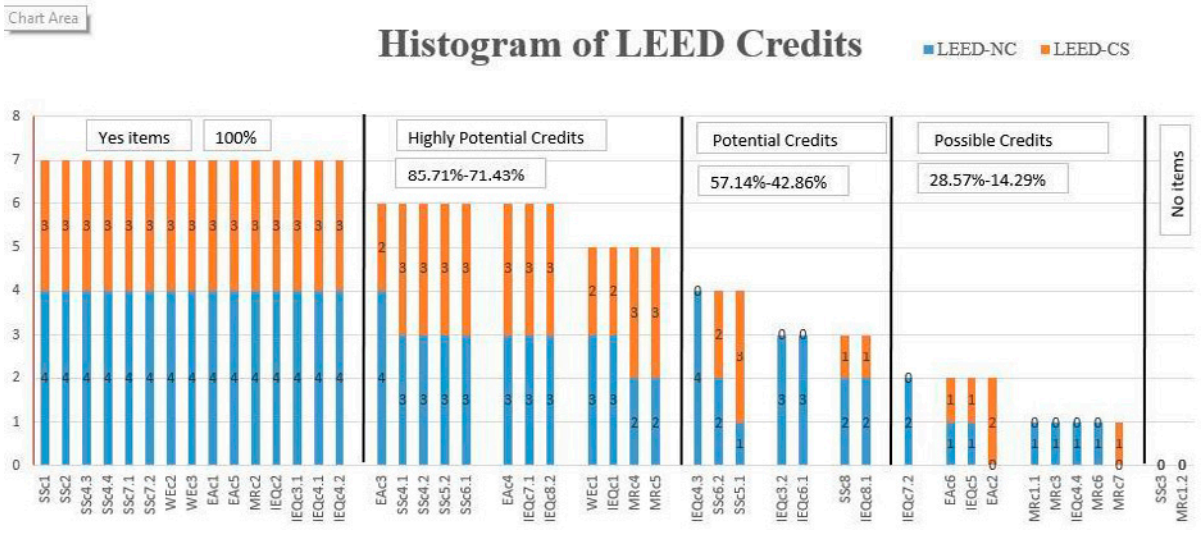

Fig. 2. Histogram of LEED Credits in Seven Building Projects in Thailand.

Main contractors must take responsibility for managing construction waste and controlling IAQ during the construction phase, and purchasing low-emitting materials involving adhesives, sealants, paints and coatings. No items which gain a credit not found in this research concern brownfield redevelopment and building reuse with interior nonstructure elements. With respect to Maybe items, they can be classified into three categories, highly potential, potential, and possible credits. The design duration of LEED projects is found to be 20% longer than that of traditional building designs. Dedicated software packages are commonly used in designing green buildings. The role of main contractors is normally excluded during the design phase, a finding contrast's to Rao and Pavan (2013) 's suggestion. In Thailand, the split review process is a common practice, construction documents and drawings related to design phase credits can be submitted via LEED online submittals prior to the construction phase. LEED-AP have an important role during construction in updating LEED scorecards, following up on LEED requirements and submitting details of materials to LEED online submittal portals. Some LEED credits change from initial design specifications for particular reasons, such as impractical design functions, unavailable materials conforming to LEED requirements, and delays concerning supporting documents. As a result, contractors also have a duty to prevent pollution, manage indoor air quality, and perform onsite waste management practices during construction. In the project delivery phase, LEED building projects normally undergo a commissioning process eight to ten months after completion to verify the correct operational practices of building systems in line with those specified in commissioning system manuals. CxA have to measure actual energy consumption in each category, summarize overall energy consumption, and compare this with predicted performance by energy simulation. This measurement and verification according to EAc5 has to be done over one year. This credit was found in most gold and platinum LEED certifications.

In conclusion, this research presents details of the implementation of project management within LEED building projects undertaken in Thailand as shown in **Fig. 3**. Architects and engineers who plan to develop future green building projects may derive useful insight from considering the findings revealed in this research when setting their project management guidelines. Several credit categories are revealed by this study of seven Thai LEED projects as comprising common credit items. The findings are potentially beneficial for future LEED or green building project management practices in Thailand.

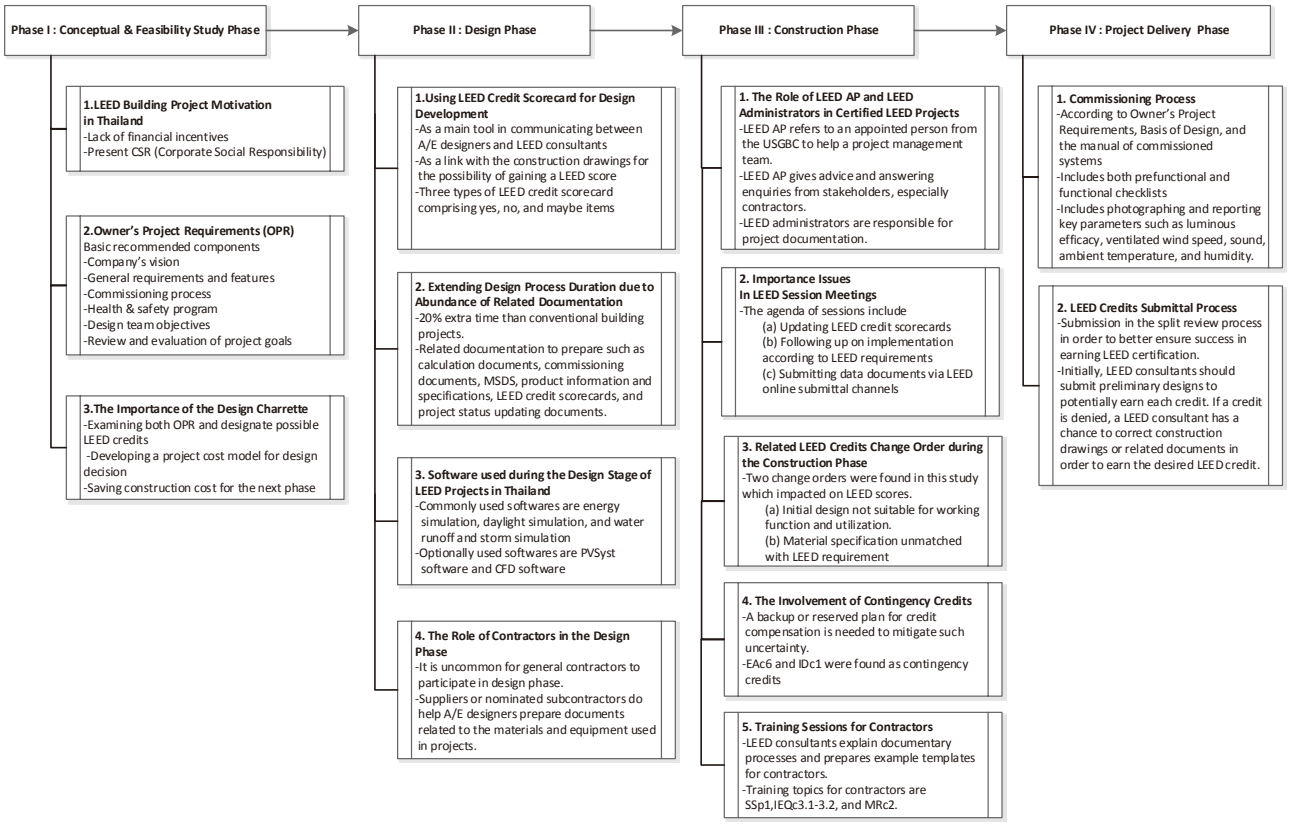

Fig. 3. Guidelines in Managing LEED Building Projects in Thailand.

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