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Article

Implementing LEED v4 BD+C Projects in Vietnam: Contributions and Challenges for General Contractor

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Abstract: Sustainable construction addresses both rising housing demand and the need to reduce energy consumption, but is not yet widespread in Vietnam, although the number of Green Building Certified projects has increased significantly since 2015, especially those with LEED certification. Certification adds value to the project but also incurs additional costs and implementation challenges for general contractors (GCs) and other stakeholders. The growing popularity of LEED buildings requires GCs to understand their role in fulfilling the LEED requirements. We therefore conducted a thorough review of the previous research on LEED v4 guidelines and their local equivalents to determine what is expected of GCs working on LEED v4 BD + C projects in Vietnam. A survey of 72 experts, engineers, and architects working in the construction sector identified the LEED tasks where Vietnamese GCs lack experience and suggested solutions to address this shortfall were developed. In particular, Vietnamese GCs lacked experience in implementing their sustainable roles. These results provide a useful foundation for Vietnamese GCs seeking to expand the scope of their LEED work and identified necessary training. Our findings will also guide future research to help GCs in Vietnam adapt to LEED's sustainability requirements and support sustainable construction in Vietnam.

Keywords: sustainable roles; LEED; contractors; Vietnam

1. Introduction

Sustainable development is vital if humanity is to meet the needs of the current world population without adversely affecting the lives of the next generation [1,2]. Over the last decade, many countries have begun to be severely affected by the effects of climate change, global warming, pollution, and the depletion of natural resources, all of which are the direct consequences of the industrial revolution [2–4]. Our growing awareness of these problems has made sustainable development a priority as it represents an important way to mitigate some of the most serious environmental impacts of industrialization [5,6]. The construction industry is a significant consumer of energy and raw materials and is thus a major contributor to global warming [7–11]. Several previous studies have indicated that globally, the construction industry consumes ~50% of the energy produced, nearly 40% of the raw materials, and 16% of the water, and is responsible for 35 % of the CO_2 produced [12–19]. It also contributes to problems such as air pollution, noise pollution, and waste pollution, among others [1,18,19]. To address these issues, sustainable construction practices and green building solutions are being implemented in countries around the world, optimizing resource use, reducing energy consumption, and minimizing the impact of buildings on the surrounding environment [20,21]. Sustainable construction has become a major global trend in the construction industry [22,23] because of its benefits and its ultimate goals of preserving our quality of life by minimizing negative environmental impacts and protecting valuable resources that will be needed by future generations. [24–26].

Green building certification systems promote sustainable construction activities by providing guidance and rewarding efforts to deliver sustainable, energy-efficient buildings [27]. Many countries have developed certification systems, including the United States (LEED; Green Building Council), the United Kingdom (BREEAM; Building Research Establishment), and France (HQE; Association pour la Haute Qualité Environnementale) [28–30]. Among these, LEED, which was first introduced in 1993, aims to minimize the adverse environmental impacts of construction activities and ensure energy/water efficiency. LEED has played a leading role in popularizing green building certification systems worldwide [6,8,31–38], and a majority of existing green building projects are now implemented based on the guidance provided by the LEED rating system or its local equivalent [39].

As in many other developing countries, Vietnam's rapid economic growth is creating considerable pressure on housing demand and raw resources, as well as environmental pollution [40,41]. Vietnam's long coastline and low-lying and densely populated delta regions make it one of the five nations in the world that are most severely affected by rising sea levels and climate change [42–44]. As the construction industry made up ~34.28 % of Vietnam's GDP in 2018 [45], the government considers promoting sustainable construction to be a potential solution that not only addresses issues related to housing demand and energy consumption but also minimizes the nation's environmental vulnerability [46]. Nguyen et al. found that the low cost of electricity in Vietnam is one of the worst drivers of investment decisions that ignore energy efficiency because of the long payback time [41]. In an attempt to address this issue, the government increased electricity prices by 8.36% in 2018, significantly increasing operating costs for buildings. It has also implemented a policy of purchasing electricity (paying US$0.0935/kWh) from owners who install renewable energy systems [47]. Due to these incentives and the better payback compared to previous green investment opportunities [6], the number of developers interested in green building projects has been increasing [41], as shown by the significant increase in the number of green certifications issued in recent years. As of December 2018, there were 174 LEED projects [48], 34 EDGE projects [49], and 51 LOTUS [50] projects in Vietnam, along with a few other certifications. These figures indicate that LEED certification is by far the most popular rating system in Vietnam.

Green building projects are increasing in popularity because of the many advantages they bring for the buildings' occupants [20]. Although LEED and other rating systems provide a way to measure a green building's quality, they also support sustainability and bring other benefits to the building users [41] due to their more stringent construction requirements and well-considered building designs. LEED's Integrative Project credits (IPp1) also require substantial input from the architects and engineers; the project manager; and all the contractors, construction consultants, and building operation experts involved from the early-project phase onward [51–53]. Currently, green building projects in Vietnam face many difficulties because of the participants' lack of relevant experience and the limited technical support available [54], which creates risks simply due to the lack of information, the need to rework sections and the increased costs incurred for construction participants such as GCs, architects and engineers, subcontractors, and the other partners involved in implementing green building projects [20,55,56]. This is especially true for GCs, who are directly responsible for ensuring the sustainability of the project [57]. With a solid understanding of their roles related to individual sustainability construction concepts, contractors will be able to achieve a better performance in delivering their sustainable project [57]. Thus, GCs need and want to understand their precise roles in implementing a LEED project, which will enable them to identify cost-efficient methods to satisfy the sustainable needs of both the building developer and the ultimate users [58]. To meet the requirements of LEED certification with a minimal increase in the need for reworking, and the additional costs this incurs, the GCs must gain more knowledge in order to fully understand what is expected of them when undertaking a LEED project [59]. This study, therefore, focuses on the sustainable roles of GCs working on a LEED v4 BD + C project by reviewing the updated "LEED v4 BD+C Technical Guidelines", previous papers examining this topic and local conditions and regulations. In order to identify the risks that arise due to inexperience and the associated need to carry out extensive remediation work, a questionnaire survey was utilized to determine the level of experience of the GCs in Vietnam who are implementing sustainable green building projects.

2. Literature Review

2.1. Previous Studies on LEED and GCs

GCs play a vital role in the success and costefficiency of any construction project; this is especially true for a sustainable building or a successful LEED project [53,57,59]. Many studies in the field of construction management and sustainable building have therefore focused on the roles of GCs and their contribution to the success of LEED projects. These studies have generally highlighted the need for greater awareness of the importance of GCs' roles in accomplishing sustainable building projects on time and within budget.

A number of studies have pointed out the GCs' roles and responsibilities and identified their sustainable site roles. Mollaoglu-Korkmaz et al. (2013) analyzed the impact of each level of integration achieved on success in meeting the sustainable goals of the project set by the owner and pointed out, in particular, the potential role of the constructor in the earlier phases of the project [60]. The U.S. Green Building Council identified 17 credits that are significant for GCs and their responsibility for implementing and documenting LEED requirements [61]. Glavinich reviewed several case studies to evaluate the role of GCs in the design process, subcontractor management, material management, LEED file collection, and the commissioning process (Cx) [62]. In his review of eight LEED projects in the US, Klehm pointed out that GCs perform three management functions in LEED project, namely, subcontractor management, materials management, and activity management [63]. Syal et al. examined the impacts of LEED credits on the GCs' function and the sustainable site practices required for green building projects [64] and analyzed the roles of GCs working on LEED NC projects and its impact on their construction management practices [65]. Frattari et al. studied the sustainable roles of the GCs in two LEED project in Italy [66], demonstrating the international significance of the LEED certification system.

Several studies focus on implementation guides to help GCs achieve their sustainability goals. Kibert (2012) described GBs systems and implementation [25]. Ahn et al. developed a process model that includes identifying the sustainable goals, implementation process, and roles of participating teams, including GCs, throughout the construction phase [67]. Bayraktar et al. (2009) provide a set of LEED implementation guidelines for GCs and others to assist them with the certification process [68]. Schaufelberger and Cloud also provided a four-step guide for GCs [69]. Son et al. surveyed GCs in Korea and the U.S. to determine their level of awareness of sustainable construction measures during the actual construction phase and developed a tool to assess and monitor the effectiveness of construction waste management, listing 17 factors that affect the performance of contractors' waste management plans [16].

Other researchers have focused on analyzing the characteristics of GCs' work on LEED projects. Opoku et al. examined the role of integrative team coordination and its influence on achieving LEED certification [70], Mollaoglu-Korkmaz et al. looked at the relationships and influence of project delivery attribute in their study of 12 green office buildings in the US [60], and Uğur and Leblebici showed the critical role played by GCs for cost estimation and the analysis of construction cost-benefit and payback periods [31]. Research by Robichaud and Anantatmula highlighted the difference it makes when GCs have LEED experience and participate early in the project [53], whereas Pulaski and Horman proposed a "continuous value enhancement process" to improve the effectiveness of management practices in sustainable construction projects [71,72]. Finally, the U.S. Environmental Protection Agency issued a set of guidelines to assist with the selection of appropriate recycled content products for construction [73].

In summary, there exists a significant need to define the role of GCs and stress the advantages gained by their involvement in the early project phases [74–76]. Previous studies have clarified the duties of GCs and other partners working on LEED projects and provided guides for improving the effectiveness of GCs. However, most have focused on GCs and LEED projects in well-developed countries [8]. There are significant differences in both the GCs' qualifications and local technical standards between Vietnam and more well-developed LEED markets [41]. Therefore, the roles of GCs in implementing site sustainability and better support systems to help them perform those roles is needed if we are to improve the competitiveness of Vietnamese GCs and enable them to participate effectively in the trend towards sustainable construction.

2.2. Identification of GCs Sustainable Roles in LEED v4 Projects

Although GCs are not the most significant contributors in terms of the additional work caused by LEED implementation, their involvement directly impacts the effectiveness and success of the project [53,57,59]. The GC or construction manager should thus be involved as early as possible in a LEED project [74–77]. Unlike traditional projects, GCs are involved in all three stages, namely, the pre-construction, construction, and closeout phases [67,77,78]. The literature examined for this study identified 18 potential roles for GCs in LEED v4 projects and these are summarized in Table 1.

(A) Pre-Construction Phase: An integrated design (ID) is a prerequisite to satisfy the requirements of LEED v4 (healthcare project only) [78]. An integrative design team should be formed to facilitate cooperation between the many different stakeholders involved, including GCs and other participants [60,79,80]. The earlier the GC begins to work with the project team, the better for the project as this will lower costs and shorten the construction schedule by setting suitable project goals at every stage [16,53]. GCs provide valuable practical advice and support the ID team's efforts to solve problems, such as procuring sustainable materials, recycling materials, creating practical designs that are appropriate for the region, developing realistic materials delivery schedules, and minimizing the pollution created by construction processes [16]. GCs are thus better able to fulfill the intentions of the design team if they have a good understanding of sustainability and its benefits, as this allows them to develop more accurate cost estimates and assess the reliability of selected products [16,53,81]. In summary, GCs should be active participants in the integrative team to enable the team to evaluate options and select LEED project goals that can be achieved at a reasonable cost and are feasible from a construction perspective.

(B) Construction Phase: The GC is responsible for the majority of the construction credits as well as several credits related to site and energy that require the involvement of other team members [78]. According to the LEED v4 guidelines, the contractor is responsible for creating an erosion and sedimentation control (ESC) plan, general LEED requirements, LEED product requirements, waste management and disposal, and indoor air quality [66]. The contractor plays an essential role in selecting the appropriate construction method and assessing constructability to meet the LEED goals [64]. The GC must also carefully review and approve all materials before they are installed, as well as being primarily responsible for collecting information from the subcontractors and submitting progress reports [77]. The GCs' on-site supervisor will oversee waste management implementation [77]. According to LEED BC+D v4 (2014), GCs play an essential role in construction activity pollution prevention (CAPP) and construction and demolition waste management planning (CDWM) [78]. The CAPP plan must meet the requirements laid down in the erosion and sedimentation section of the 2012 U.S. Environmental Protection Agency (EPA) Construction General Permit (CGP) regulations or their local equivalent [78]. As these LEED requirements are more rigorous than the local equivalent in Vietnam [82–84], GCs need to understand the rules and be prepared to comply with the more stringent LEED requirements. Regarding fundamental commissioning and verification criteria, GCs only take the lead role for projects where the ground floor area (GFA) is below 1860 m^2 [78]. For larger projects, a commissioning authority (CxA) will assume the primary responsibility with support from the GC. It is essential for GCs to collect all the material data sheets and take extensive job site photographs. Many credits require documentation to be prepared continuously for submission as part of the LEED certification process. GCs must coordinate with the LEED consultant when collecting data on materials and the installation process for mid-project audits to review compliance with the LEED credit requirements [66]. They must also periodically inspect the indoor air quality control measures implemented, identify any issues that need to be corrected, and record their observations on a checklist [77]. At the end of construction phase, the flush-out and air testing are conducted by GC or a special contractor.

(C) Closing Phase: The GCs' most crucial task in this phase of the project is to gather the necessary documents and provide these to the LEED consultant. These include a list of LEED related materials, the quantity of each utilized, purchase reports, datasheets from manufacturers, environmental certificates, and so on (Frattari, 2012; Schaufelberger & Cloud, 2009). GCs that lack previous LEED experience are likely to need assistance from LEED consultants when developing their LEED credit template and LEED site checklist, as well as when preparing documents for submission [66]. GCs may also be responsible for performing an additional building flush-out test before the building's occupant's move in [78], but this is optional, quite costly, and uncommon in Vietnam.

Table 1. List of GCs' roles in LEED projects identified in the literature.

ID [1]	LEED v4 Credits	GC's Sustainable Roles/Function
IPp1	Integrative project team member	IP1: Integrative Process worksheet of GC [66,67,69,70,77,78,84–90] (**A**).
SSp1 *	Construction activity pollution prevention	SS1: Erosion and sedimentation control (ESC) plan [25,64,66,78,87,89,90] (**A**). SS2: ESC Implementing weekly report [25,66,69,70,77,78,82–84,89–92] (**B**). SS3: Report of compliance with EPA CGP [25,64,66,69,77,78,89,90] (**B**,**C**).
SSc2	Construction activity management for greenfield protection	Following the strategies listed in SSp1 "Construction Activity Pollution Prevention" [17,78,90] such as preventing construction damage to green fields, soil poisoning, soil compaction and so on.
WE	All water efficiency credits	WE1: Report of the irrigation systems purchase [66,77,78] (**C**). WE2: Report of the water use equipment purchase (it can be replaced by on-site testing) [64,66,77,78,90] (**C**). WE3: Report of the water consumption monitoring system purchase [64,66,78] (**C**).
EAp1 *	Fundamental commissioning (GFA < 1860 m^2—major role)	EA1: Fundamental commissioning (Cx) & verification plan [64,69,78,89,90] (**B**). EA2: Fundamental Cx & verification implementing report [64,78] (**B**,**C**).
	(GFA > 1860 m^2—supporting role)	EA3: Supporting fundamental Cx contractors by providing the necessary documentation [64,66,77,78] (**B**,**C**).
EAc1	Enhanced commissioning. [v4]	Not a GC roles. GCs only provide the necessary documentation (Envelope material) [64,66,77,78,90].
EQc4	Indoor air quality assessment [v4]	Made by the "Flush-Out" or "Air testing" contractor, GCs support for the on-site preparation (**C**).
EAc6	Enhanced refrigerant management	EA4: Report of the fundamental refrigerant management plan (**C**) [66,78].
MRp2	CDWM Planning	MR1: Construction and demolition waste management plan (**B**) [64,66,69,78,90].
MRc2	Environmental product declaration [v4]	AD1: Report of compliance with LEED's material purchase requirements (**B**,**C**) [25,59,64,66,69,77,78,89,90].
MRc3	Sourcing of raw materials [v4]	
MRc4	Material ingredients [v4]	
EQc2	Low-emitting materials [v4]	
MRc5 *	Construction & demolition waste management (CDWM)	MR2: Report of CDWM Plan implementing [64,66,69,77,78,89,90,92] (**B**). MR3: Report of implementing the construction and demolition waste management result [64,66,69,77,78,89–91] (**C**).
EQc3 *	Construction indoor air quality management	EQ1: Report of Implementing the construction indoor air quality management plan [25,64,66,69,77,78,90] (**B**). EQ2: Environmental tobacco smoke control policy [66,78] (**B**,**C**).

[1]: The IDs used for the credits are the same as those used on the leeduser website; * indicates the LEED V4 credits where GCs play a significant role; [v4] these credits differ markedly from those used in LEED V3. (**A**) The main phase is pre-construction phase; (**B**) the main phase is construction phase; (**C**): the main phase is closing phase.

3. Research Methods

3.1. Questionnaire Design

Questionnaire surveys are used extensively to collect data on professional opinion in the construction management field and green building research [92]. A two-part survey questionnaire was therefore created for this study to gather expert perspectives on the current experience of Vietnamese GCs implementing LEED projects. The first part of the questionnaire gathers background information on the responders, including the field they work in, their years of experience, and their green building experience. Respondents working in non-related fields or with less than one year of experience were eliminated. The second questionnaire part was developed based on the "LEED Reference Guide for Building Design and Construction", 2013 Edition, and the findings of previous researchers presented above in the literature review. A pilot questionnaire was tested to ensure its comprehensibility and suitability for the intended purpose by administering it to a green building expert with nearly ten years of experience in Vietnam. Four of the 22 GC roles were removed based on the expert's feedback, as they are seldom applicable to LEED projects in Vietnam. The final questionnaire consisted of 18 questions examining the topics presented in Table 1 and respondents were asked to indicate their experience of the GCs implementing the various LEED roles using a 5-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree). Respondents were also asked to assess the LEED experience levels of contractors that they had worked with, or coordinated in previous building projects. The 5-point Likert scale is widely used in green building studies because it is unambiguous and easily interpreted [93].

3.2. Data Collection

The target population for this research was the engineers and architects working in the construction field in Vietnam who had extensive work experience and understanding of Vietnamese GCs. As sampling this entire population would be costly to implement, the nonprobability sampling technique was deemed suitable for selecting the sample based on the purpose of the study. Following the study of B.G. Hwang (2017) [92], Equation (1) was utilized to determine the minimum sample size required for significance. To maximize the number of samples collected, a relatively high standard deviation of 4 was selected and a minimum error factor of 1; the minimum sample size of the survey was thus 62.

$$n = \left(\frac{\mathrm{Zs}}{\mathrm{E}}\right)^2 = \left(\frac{1.96 \times 4}{1}\right)^2 = 61.5 \tag{1}$$

- n: minimum sample size.
- S: sample standard deviation
- E: error factor,
- Z = 1.96, equal to 95 percent of the confidence

The survey email was sent to potential participants on a list of surveyors' email collected by researchers in the construction department of Ho Chi Minh City University of Technology (HCMUT). This list includes experts working in the construction sector in the southern region in Vietnam, as was originally collected and used for previous studies in the construction management field by graduate students attending HCMUT. The southern region is a useful location for green building studies since the most recent data (January 2019) indicates 64 of the country's 88 certified green building projects are located in this area. Two versions of the survey questionnaire based on the topics in Table 1, in English and Vietnamese, were created using the Google survey. A link to the questionnaire was included in an email describing the objectives of the study and inviting recipients to participate in the survey. Emails were sent to 542 people on the HCMUT email list and posted on several construction and architecture forums in Vietnam. Recipients were also encouraged to share the survey with any of their colleagues who are interested in green building projects. A total of 72 respondents completed the survey, ~13.3% of the emails sent out. This result is lower than the usual response rate of approximately 20 to

30% [92], suggesting that many Vietnamese construction experts still have little interest in sustainable construction. The sample size is larger than the minimum number of samples required based on the calculation in Equation (1).

The survey respondents had diverse backgrounds and were all active in the construction sector. As the data presented in Figure 1 demonstrate, the majority had 1–5 years of experience, with only a few having more than ten years of experience. Given the growth in green building projects in recent years, it is not surprising that the most experienced respondents were engineers. There were two main groups of experts: general contractor's staff and non-general constructor's staff. Half of the respondents were green building experts working for GCs, and the remaining half were evenly split between the other groups. This diversity was useful, introducing more perspectives on the characteristics needed for GCs working on LEED projects.

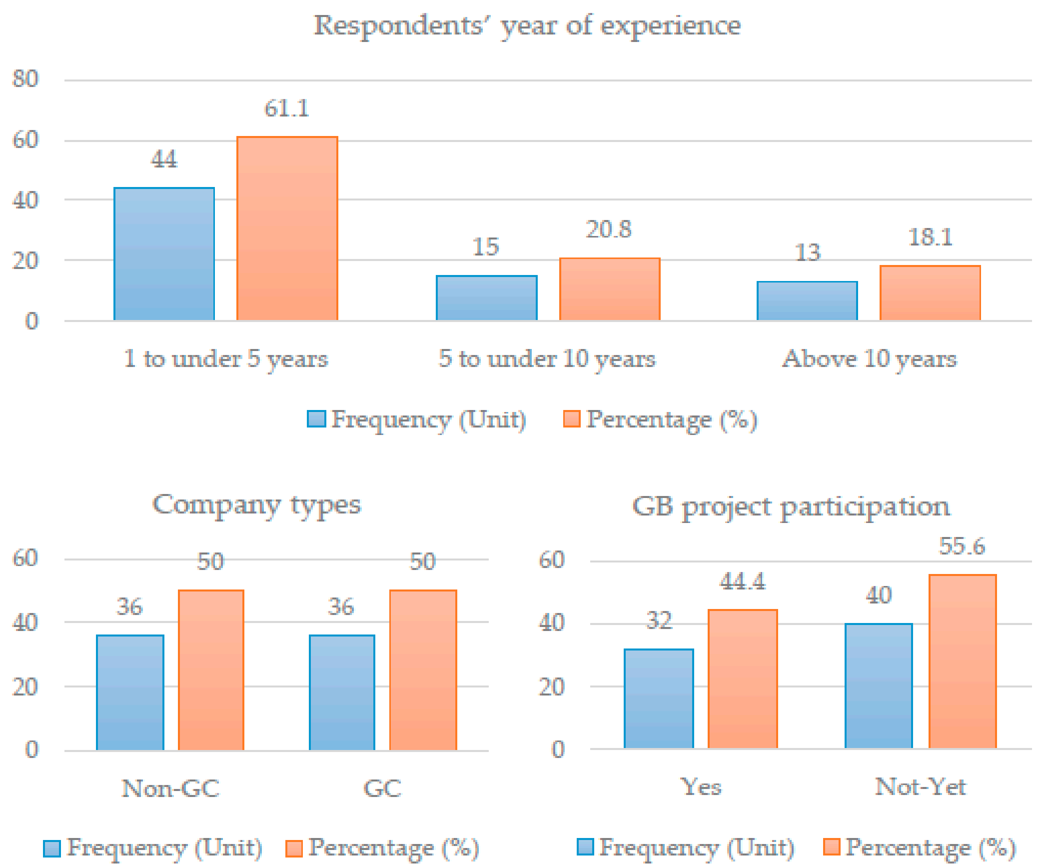

Figure 1. The respondents' professions.

3.3. Statistical Analysis

The data collected were statistically analyzed using the five-step data analysis framework, which is following the studies of A.Darko et al (2017), B.G. Hwang (2017), and S. Pushkar (2018) [1,92,94]. The data were analyzed by using the SPSS 20.0 software package.

1. Cronbach's alpha was used to evaluate the reliability of data for further analysis.

2. After that, the mean value ranking technique was applied to identify and prioritize the roles where Vietnamese GCs are most inexperienced.

3. The Shapiro–Wilk test was then utilized to test the normality of the data collected with the null hypothesis that each sample data came from a normally distributed population. At a 95% level of confidence, the null hypothesis of this test is that the collected data is normally distributed. If the p-value is less than the 0.05, the null hypothesis is rejected and there is evidence that the data tested are not normally distributed.

4. Identifying the roles where GCs lacked experience-based on the significance of the mean values via a t-test to determine whether the difference of the mean of each GCs' LEED role was close to the mean value on the Likert-scale. At a 95% level of confidence (*p*-value: 0.05), and against a test value of 3.00 (neutral on the rating scale), the one-sample t-test was therefore conducted for significant differences in the mean values for the experience levels of the Vietnamese GCs implementing LEED projects. The null hypothesis of the t-test in is H0, and the mean value is not statistically significant. The null hypothesis H0 would be accepted if the *p*-value of the GCs' role task is more than 0.05, and the alternative hypothesis H1 "the mean value is statistically significant" would be rejected.

5. Following the studies of A. Darko at al. (2017), the ANOVA test (parametric tests) or Kruskal–Wallis test (nonparametric tests) are applied to identify any statistically significant differences [1]. However, in this study, the Wilcoxon–Mann–Whitney (WMW) and Cliff's effect size nonparametric tests were replaced to compare the significance of the mean values of two or more groups because of homoscedasticity uncertainty of the data. The data are presented as the median ± interquartile range (IQR: 25th to 75th percentile). According to suggested sampling structures of S. Pushkar (2018) study, "Cliff's δ was used to measure the substantive significance (effect size) between two unpaired groups", and is calculated as $\delta = \#(x1 > x2) - \#(x1 < x2)/(n1n2)$ [94]. As a result, the effect size is considered "negligible" if $|\delta| < 0.147$, "small" if $0.147 \leq |\delta| < 0.33$, "medium" if $0.33 \leq |\delta| < 0.474$, or "large" if $|\delta| \geq 0.474$ [94]. Where x1 and x2 are scored within each ground and n1 and n2 are the sizes of the sample groups, and the cardinality symbol # indicates counting. Furthermore, an approximate WMW was conducted while the sample sizes were $n1 = n2 \geq 9$ to determine statistical difference (*p*-value) between two unpaired groups.

4. Results and Discussion

4.1. Data Analyzing

In this study, the relative importance of the GCs' experience of various LEED roles was evaluated using a 5-point Likert scale. The Cronbach's alpha coefficient of the data packet was found to be 0.918, which is above the high-reliability threshold of 0.7 [95], thus indicating the data has high reliability. In the second step, the full results of the survey, as well as the relevant statistical test results, are shown in Table 2. From the results of the Shapiro–Wilk test, no *p*-value values of the entire GCs' roles were above a confidence level of 0.05, indicating that the data collected from the survey was not a normal distribution.

Based on the results presented in Table 2, 89% of the survey results had mean values below 3 (neutral level). The respondents' overall rating for the GCs' experience in implementing LEED roles was only 2.66, indicating that respondents do not consider that GCs have adequate experience for in implementing their LEED roles. This shows a serious lack of experience and indicates that GCs need to be provided with more training if they are to fulfill their responsibility for implementing these LEED roles, which concern fundamental commissioning, refrigerant management, material documentation, managing indoor air quality during construction, and environment product declarations. Only two GC LEED tasks had a mean value greater than 3.0, namely IP1 (Integrative design support; 3.39) and EAQ2 (Smoking control policy; 3.42). This suggests that GCs in Vietnam have approached and supported investors in the process of project formulation, possibly because the GCs who win these contracts have worked with investors and thus have a greater understanding of the projects and their aims. Also, most reputable contractors have implemented a smoking control policy on sites since the Vietnamese government issued a smoking ban for workplaces in June 2018 [96].

Table 2. Mean value ranking, t-test and Shapiro–Wilk test result in the GC LEED roles.

All (n = 72)											
Code	**Mean**	**SD**	**Rank**	***p*-value (t-test)**	**Sig. (SW)**	**Code**	**Mean**	**SD**	**Rank**	***p*-value (t-test)**	**Sig. (SW)**
EQ2	3.42	1.3	1	0.006 *	0.00 [a]	SS1	2.58	1	10	0.000 *	0.00 [a]
IP1	3.39	1	2	0.002 *	0.00 [a]	SS3	2.54	1	11	0.000 *	0.00 [a]
WE2	2.89	1	3	0.369	0.00 [a]	EA3	2.53	1	12	0.000 *	0.00 [a]
MR1	2.85	1	4	0.206	0.00 [a]	EA1	2.42	1	13	0.000 *	0.00 [a]
WE1	2.83	1	5	0.165	0.00 [a]	EA4	2.33	1	14	0.000 *	0.00 [a]
MR2	2.82	1.1	6	0.16	0.00 [a]	EA2	2.32	1.1	15	0.000 *	0.00 [a]
WE3	2.76	0.9	7	0.037 *	0.00 [a]	EQ1	2.32	1	16	0.000 *	0.00 [a]
MR3	2.67	1	8	0.005 *	0.00 [a]	AD1	2.31	1.2	17	0.000 *	0.00 [a]
SS2	2.6	0.9	9	0.001 *	0.00 [a]						

Notes: * t-test results with *p*-values below 0.05, suggesting a significant difference in the mean value. [a]: Shapiro–Wilk test results with a *p*-value less than 0.05, indicating the data is not a normal distribution.

This study used statistical methods including mean values, ranking techniques, and one-sample t-tests to identify any statistical significant roles that GCs are lacking experience. Although the data from the survey is not a normal distribution, according to the central limit principle the size of samples is more significant than 30, and therefore can be accepted as a normal distribution, so the t-test result can be considered reasonable [97]. The results of the t-test, shown in Table 2, suggested that Vietnamese GCs are lacked experience in most of their roles. The one-sample t-test results and the mean-value present 12/17 GCs roles significant lacked experience when carrying out these critical LEED roles. It included credits, which GCs have played a significant contribution in the success of LEED projects, such as “Construction activity pollution prevention”, “material criteria”, “Construction indoor air quality management”, and “Construction & demolition waste management”. Finally, an approximate WMW test was conducted. However, if experimental units are pooled from the different sampling frames, the problem of sacrificial pseudo-replication can occur [94]. Thus, the sample from each compared group was randomly selected. To perform an approximate WMW test, minimum sample size was n1 = n2 ≥ 9. The number of sample size with the total number of respondents and number of randomly selected respondents’ data which is presented in Table 3.

Table 3. The number of sample size and the number of randomly selected.

Company Types	**Sample Size (n)**	
	Yes	**Not-yet**
Non-GC	18 (18)	18 (18)
GC	14 (14)	22 (14)

There are considerable differences in opinion among expert groups that can lead to errors in mean-value, particularly those who had (or not yet) experience in LEED project or the GC/non-GC. Therefore, the group of respondents who have (or never) participated in the LEED project in the group from was statistically evaluated individual working field (GC/non-GC) sampling frame analysis (by an approximate WMW test). Data analysis results using the WMW test and Cliff’s delta by grouped experienced/non-experience and GC/non-GC groups are presented in Table 4. According to Tables 2 and 4, the author divides the roles of GCs through the survey into four main groups: (i) experienced and no statistical difference, (ii) experienced and statistically different, (iii) inexperienced and no different Statistical differences, and (iv) non-experienced and statistical differences. As the result of GC respondents, group (i) includes EQ2, group (ii) includes IP1, WE1, WE2, MR1, and MR2; group (iii) includes SS1, SS2, and EA3; and group (iv) includes SS3, WE3, EA1, EA2, EA4, MR3, and EQ1. For Non-GC respondents, group (i) includes MR1; group (ii) includes IP1, WE1, WE2, MR2, and QE2; group (iii) includes SS1, SS2, EA2: EA4, and MR3; and group (iv) includes SS3, WE3, EA1, EA3, and EQ1. A summary of Group (iv) for the GC/Non-GC roles WE3, EA1, EA2, EA3, EA4, MR3, and EQ1 is linked to lack of experience, but there are statistical differences between groups of people answer each participant/have never participated in the green building project. Respondents who participated in green building projects have a larger mean-value than the other groups. It demonstrates that the roles in this group can be performed better than the overall respondents expected. Summary of the group (iii) of GC and Non-GC, the roles SS1; SS2; EA2: EA3; EA4; MR3 are agreed by both groups of respondents that GC lacks experience in implementing that Vietnamese contractors need to give priority to the training of their staff.

Table 4. Cliff's δ and the Wilcoxon–Mann–Whitney (WMW) test result.

ID	Position	Sample Size n1 = n2	GB Experience						Cliff's Delta	*p*-Value	NFSAs
			Yes			No					
IP1	Non-GC	18	3.78	±	0.79	3.11	±	1.15	0.353	0.071	Suspended
	GC	14	3.71	±	0.88	3.00	±	1.00	0.418	0.049	Positive
SS1	Non-GC	18	2.72	±	0.73	2.56	±	1.07	0.114	0.592	Negative
	GC	14	2.57	±	0.90	2.36	±	0.97	0.184	0.381	Negative
SS2	Non-GC	18	2.83	±	0.69	2.50	±	1.12	0.199	0.295	Negative
	GC	14	2.43	±	0.98	2.57	±	0.98	-0.036	0.866	Negative
SS3	Non-GC	18	2.72	±	0.73	2.28	±	1.15	0.301	0.140	Suspended
	GC	14	2.86	±	1.12	2.29	±	0.80	0.306	0.150	Suspended
WE1	Non-GC	18	3.22	±	0.92	2.39	±	0.89	0.461	0.011	Positive
	GC	14	3.14	±	0.99	2.36	±	0.81	0.408	0.054	Suspended
WE2	Non-GC	18	3.28	±	0.93	2.44	±	0.90	0.464	0.010	Positive
	GC	14	3.36	±	1.04	2.36	±	0.89	0.515	0.016	Positive
WE3	Non-GC	18	3.11	±	0.87	2.33	±	0.82	0.454	0.012	Positive
	GC	14	3.21	±	0.86	2.36	±	0.89	0.505	0.016	Positive
EA1	Non-GC	18	2.67	±	1.05	2.11	±	1.10	0.261	0.111	Suspended
	GC	14	2.79	±	1.01	2.21	±	0.56	0.301	0.137	Suspended
EA2	Non-GC	18	2.44	±	1.12	2.06	±	1.08	0.180	0.263	Negative
	GC	14	2.79	±	1.01	2.21	±	0.67	0.296	0.155	Suspended
EA3	Non-GC	18	2.94	±	1.03	2.22	±	1.13	0.366	0.046	Positive
	GC	14	2.71	±	0.80	2.36	±	0.61	0.260	0.201	Negative
EA4	Non-GC	18	2.67	±	1.15	2.61	±	1.06	0.059	0.794	Negative
	GC	14	3.00	±	0.76	2.14	±	0.74	0.551	0.008	Positive
MR1	Non-GC	18	2.72	±	0.93	2.50	±	0.96	0.088	0.712	Negative
	GC	14	3.14	±	0.91	2.43	±	0.90	0.418	0.047	Positive
MR2	Non-GC	18	3.00	±	0.94	2.50	±	1.17	0.261	0.185	Suspended
	GC	14	3.36	±	0.72	2.36	±	0.89	0.577	0.007	Positive
MR3	Non-GC	18	2.89	±	0.81	2.44	±	1.26	0.242	0.229	Negative
	GC	14	3.36	±	0.89	2.50	±	1.05	0.429	0.045	Positive
EQ1	Non-GC	18	2.67	±	1.00	2.22	±	1.18	0.245	0.178	Suspended
	GC	14	2.57	±	0.73	2.00	±	0.76	0.429	0.036	Positive
QE2	Non-GC	18	3.44	±	1.07	2.67	±	1.37	0.337	0.113	Suspended
	GC	14	3.86	±	0.99	3.36	±	1.23	0.219	0.307	Negative

4.2. Differences with Developed Countries

In general, the role of GCs in LEED projects in Vietnam is quite similar to projects in other countries. For most criteria, like construction activity pollution prevention, commissioning activities are compliant with equivalent standards in the US. However, as a result of inexperience, the Vietnamese GC's role is limited and replaced by LEED consultants or foreign contractors, especially jobs involving Cx and flush out or air testing. Compared to well-developed countries such as the US, contractors in Vietnam lacked experience in the majority of LEED's work. Especially the group roles (iii) such as SS1, SS2, EA2: EA3, EA4, and MR3. The group of sustainable site credits (SS1 and SS2), which comply with U.S. EPA requirements, creates a new challenge for Vietnamese general contractors. The Cx process and flush-out or air testing (EA2–EA4) are not yet common in Vietnam and may not be mentioned in the bidding process. Construction waste management implementation (MR3) is still a big problem for Vietnamese contractors, as the government has regulations on solid waste management in construction, but it has not yet been applied in real conditions [96]. Furthermore, the construction materials in Vietnamese market are also often lack of necessary green certificates for LEED evident, and it also creates confusion for the GC in the process of purchasing materials. Besides, language differences are also a barrier for contractors in Vietnam because it generates extra documents and consumes human resources as well as time. Vietnamese general contractor also lacks experience in collecting LEED records of materials and equipment. Therefore, hiring LEED specialists and conducting training programs is necessary for contractors to improve the effectiveness of their first LEED jobs. The results of the study also indicate that contractors need to prioritize training and pay more attention to the work in the group (iii), and group (iv), especially the jobs in which they play a major role.

5. Conclusions

In recent years, the demand for sustainable construction to offset the shortage of resources and minimize the environmental impacts of fast-growing industries is evidenced by the increase in the number of green-certified buildings. If they are to remain competitive and thrive in this new market, the study helped the Vietnamese GCs to develop a better understanding of their sustainable roles and learn how to adapt cost-effectively and engage in more sustainable green building practices. The following was identified.

1. This review found that Vietnamese CGs are expected to play a significant role in four types of LEED v4 credits, namely, the implementation of the Erosion and Sedimentation Control Plan, Construction & Demolition Waste Management, Construction Indoor Air Quality Management, and Fundamental Commissioning. In particular, Cx and flush out or air testing can be done by other (foreign) contractors/experts. However, it is necessary to define the role of GC in the process of bidding and contract making.
2. The Vietnamese GCs lack experience in implementing LEED credits, which included SSp1 "Construction activity pollution prevention" (SS1–SS3), EAp1"Fundamental Commissioning" (EA1–EA3), "Construction & demolition waste management" (MR3), and "Construction indoor air quality management". Moreover, Vietnamese GC also lack experience in selecting and documenting the purchasing of LEED materials.
3. Currently, Vietnamese regulations and standards do not have such strict requirements compare to LEED requirements. Therefore, works such as ESC and Cx should be planned according to the requirements or standards which are mentioned by LEED.
4. The results of the study showed that the Vietnamese general contractors were lacked experienced in most LEED roles. In which priority is given to training programs on LEED for the following jobs (iii); SS1, SS2, EA2: EA4, and MR3, which included "Erosion and sedimentation control" (SS1 and SS2), "Fundamental commission for project less than 1860m2" (EA2), "Enhanced refrigerant management" (EA4), and "Construction and demolition waste management" (MR3).

Given the limited empirical studies on GCs' experience in implementing LEED roles, especially in Vietnam, the practical results of this study make a substantial contribution to the green building body of knowledge and are expected to encourage sustainable construction in Vietnam. Furthermore, the findings of this study will serve as a valuable reference to assist students and project managers, developing a practical construction implementation to achieve more sustainable building developments. These findings highlight the importance of involving the GC integrated design process to provide a more efficient building project and sustainable construction. Providing the GC with an outline of the scope of work, and the advantages and disadvantages inherent in a LEED project, will improve the GC's performance and support the developer's decision to invest in a green building project, thus contributing to sustainable construction in Vietnam.

As with most research, this study suffers from a number of limitations that remain to be addressed in future research. Regarding the population of the study, most of the experts participating in the survey come from the southern part of Vietnam, where most of the LEED-certified projects are concentrated. However, a survey dataset with a larger population and nationwide distribution may be more reliable. Although the goal is to promote the construction of sustainable green building practices and sustainable construction in Vietnam, this research focuses solely on GCs' roles in LEED projects, building a foundation for future studies on the impact of LEED certification on GCs and the optimization of LEED-related tasks for Vietnamese GCs. The GC roles identified will provide a useful starting point for efforts to reduce the effects of LEED's incremental work on GCs and optimize these tasks to introduce greater cost efficiency for projects and GCs. However, these issues were outside the scope of this research to investigate the GCs' roles in implementing LEED project, which identified their lack of experience related to many of their expected roles. Future studies should extend the original research topics to examine the roles of the building developers and/or the project management teams in implementing popular green building rating systems such as LEED in Vietnam.

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