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A Preliminary Investigation of the Transition from Green Building to Green Community: Insights from LEED ND

Peng Wu [1,*], Yongze Song [2], Xin Hu [2] and Xiangyu Wang [2]

[1] School of Design and the Built Environment, Curtin University, Perth, WA 6102, Australia
[2] Australasian Joint Research Centre for Building Information Modelling, Curtin University, Perth, WA 6102, Australia; yongze.song@postgrad.curtin.edu.au (Y.S.); Xin.hu@curtin.edu.au (X.H.); xiangyu.wang@curtin.edu.au (X.W.)
* Correspondence: peng.wu@curtin.edu.au; Tel.: +61-8-92664723

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Abstract: The Leadership in Energy and Environmental Design for Neighborhood Development (LEED ND) rating system has been considered one of the major tools to assess the performance of green communities. However, few studies have been conducted on how the traditional focus on green building can be effectively transitioned to green communities. In order to facilitate the transition process, this paper reviews and analyzes the credits obtained from LEED ND 2009 certified plans. A total of 55 projects were identified from the LEED project directory of the U.S. Green Building Council. The performance of these neighborhood development projects, including project landscape, percentage of achievement and predictors of LEED ND rating, was analyzed. The performance was then compared with the performance of green buildings certified under LEED New Construction (LEED NC). The results indicate that there is an unbalanced allocation of credits to economic, social and environmental sustainability in the LEED ND rating. In addition, green infrastructure and building credits, such as wastewater management, on-site renewable energy and solar orientation, have extremely low percentage of achievement, indicating that these credits should be redesigned. The results provide useful insights for developers to prepare for LEED ND certification and for regulatory bodies to improve the performance of the current LEED ND rating system.

Keywords: LEED ND; sustainable community; sustainable development; green building

1. Introduction

Green building has been rapidly recognized for its contribution towards sustainable development. Various assessment frameworks and rating systems have been developed to assess a building's environmental performance and integrate sustainable development into building and construction processes [1]. The Leadership in Energy and Environmental Design (LEED) is recognized as one of the most widely adopted initiatives to evaluate the sustainable performance of buildings and communities [2]. The most commonly adopted rating system in LEED is LEED New Construction (LEED NC), which focuses on the construction of new commercial and residential buildings and major renovations. Many studies have therefore focused on the use of LEED NC in the building industry on the requirement of daylighting design in order to improve visual satisfaction of occupants in a LEED Gold laboratory building [3] and whether occupant satisfaction differs significantly in LEED and non-LEED buildings [4]. These studies offer useful insights and can guide individual building design and construction, which can promote the development of high performance buildings.

Due to the rapid increase in urbanization, sustainable neighborhoods and sustainable communities have also been focused upon, along with green buildings. The definition of sustainable neighborhoods or sustainable communities varies across different studies [5]. However, there are a few common characteristics which are recognized consistently, such as sustainable transport, mixed land use, diversity and passive solar design [6,7]. LEED Neighborhood Development (LEED ND) is recently developed to capture the interaction between buildings and their infrastructure by the U.S. Green Building Council (USGBC). Similar to LEED NC, LEED ND has a set of assessment categories, including smart location and linkage, neighborhood pattern and design, green infrastructure and buildings, innovation, as well as regional priority credits. Depending on the number of credits achieved, neighborhood development can be rated as Certified, Silver, Gold or Platinum.

LEED ND is considered to be an important rating system to assess neighborhood performance [8]. However, there are limited studies which analyze LEED ND certified projects to understand the contribution of LEED ND to the development of sustainable communities. A preliminary literature review indicated that previous investigations mainly focused on the initial version of LEED ND, named LEED ND pilot. For instance, three LEED ND pilot studies were used to examine which sustainability criteria are integrated into the rating system [9]. 224 LEED ND pilot projects were used to explore the geographical variations of these projects [10]. However, it should be noted that the sunset date of the LEED ND pilot is 31 July 2016, which means that projects will no longer be able to submit for review under the pilot version [11]. As the performance of previous LEED certified projects can offer useful guidance for future projects because the reveal of point allocation from previous projects is important to understand how projects and rating systems evolve to accommodate the ever-changing sustainability requirements [12]. Nevertheless, there has been a lack of investigations about this issue in the context of the most recent version of LEED ND. More importantly, as the current focus of sustainable development in the building industry is placed heavily on green buildings, it is necessary to investigate how the focus can be effectively transitioned to a focus on green neighborhoods, which involves a link between buildings and their relevant infrastructure.

The aim of this paper is therefore to: (1) analyze the credit achievement pattern of LEED ND using various indicators, including project landscape, percentage of achievement and predictors of certification level; (2) investigate the transition from green building to green neighborhood development by comparing the credit achievement pattern of LEED ND and LEED NC; and (3) provide useful recommendations for practitioners and regulatory authorities to implement and improve the LEED ND rating system. The paper is organized into the following sections. Section 2 provides an overview of LEED ND. The research method is presented in Section 3. Section 4 offers the results of this study as well as a comparison between LEED ND and LEED NC. Section 5 provides a discussion and implications of the results and Section 6 concludes this study.

2. Overview of LEED ND

LEED is recognized as one of the most widely accepted assessment systems to evaluate the sustainable performance of buildings and communities. A variety of rating systems within the LEED system have been developed to evaluate different types of building developments, including new construction (NC), existing buildings (EB), commercial interiors (CI) and neighborhood development (ND). Specifically, LEED NC focuses on new commercial and residential buildings, as well as major renovations. LEED EB evaluates the sustainable performance of existing building operations [4]. Similarly, LEED CI focuses on the performance of spaces, primarily in office, retail and institutional buildings [13] and LEED ND aims at providing a benchmarking system for improving neighborhood design [10].

LEED ND was created by the USGBC, along with the Congress for New Urbanism and Natural Resources Defense Council [13]. The primary focus of LEED ND is that, unlike other LEED rating systems (such as LEED NC) which focus on isolated building projects, it places emphasis on neighborhood, which is a combination of buildings and relevant infrastructure [13]. The aim

of the rating system is to integrate three principles, which are green building, smart growth and new urbanism, into a comprehensive rating system to evaluate neighborhood performance [13]. Green building refers to a systematic approach to achieve sustainability in the building's life cycle [14,15]. Smart growth refers to the achievement of economic and social growth with various conservation strategies that can protect the environment [16]. As such, many principles, such as mixed land use, compact building design, walkable neighborhoods and various transportation choices, have been implemented to achieve smart growth [10]. In addition, new urbanism is promoted as a set of ideas to mitigate urban sprawl by encouraging infill development. It has a few principles, including walkability, connectivity, mixed-use and density, mixed housing, quality urban design, traditional neighborhood structure, increased density, green transportation, sustainability and quality of life [9,10].

LEED ND has two major versions, including LEED ND pilot and LEED ND 2009. LEED ND pilot was initiated by the USGBC in April 2007. Similar to other LEED rating systems, LEED ND pilot has a few main prerequisites and credits. The main categories of LEED ND pilot include: smart location and linkage, pattern and design, green construction and technology, as well as innovation and design process. The LEED ND pilot version certified a total of 101 projects. By investigating these pilot projects, a number of issues were identified. For example, Knack argued that although being identified as neighborhood development rating system, LEED ND focuses on planning around specific building projects or sites, excluding many other important economic and social factors [17]. Similarly, it is found that due to the density requirement, compared with urban areas, rural areas may be difficult to be certified by LEED ND, leading to significant regional variations that need to be addressed [9]. This is in accordance with Retzlaf who stated that there is a lack of regional diversity in the rating system [18].

In order to address the aforementioned problems of the pilot version and to ensure a continuous improvement of the rating system, LEED ND 2009 was later released by the USGBC. LEED ND 2009 has five main categories, including [19]:

- Smart location and linkage (SLL). Smart location and linkage addresses the question of "where to build" and focuses on site selection. The larger credits in this category include preferred locations (10 points) and locations with reduced automobile dependence (7 points).
- Neighborhood pattern and design (NPD). Neighborhood pattern and design addresses the question of "what to build" and focuses on new urbanism. The larger credits in this category include walkable streets (12 points), mixed-income diverse communities (7 points) and compact development (6 points).
- Green infrastructure and buildings (GIB). Green infrastructure and buildings addresses the question of "how to mitigate environmental impacts" and focuses on green building practices. The larger credits in this category include certified green buildings (5 points) and stormwater management (4 points).
- Innovation and design process (IDP). This category encourages exemplary performance and the inclusion of LEED Accredited Professional.
- Regional Priority credits (RP). This category aims to integrate local variations into the evaluation system.

Table 1 summarizes the re-allocation of credits from the pilot version to the 2009 version. As can be seen in Table 1, one major change in LEED ND 2009 is the introduction of regional priority points to address local priorities. Regional priority points are bonus, not new points [2]. The other important change is the highlighted importance of neighborhood design. Neighborhood pattern and design has 5 more points in LEED ND 2009 due to the importance of neighborhood design rather than individual building designs. In addition, the thresholds of many credits within neighborhood pattern and design, such as diversity of uses, have been tightened significantly, as many pilot projects have easily earned the maximum points.

Table 1. A summary of the re-allocation of Leadership in Energy and Environmental Design for Neighborhood Development (LEED ND) credits.

Assessment Areas	Versions		Percentage Change
	LEED–ND Pilot	LEED–ND 2009	
Smart location and linkage (SLL)	30 (28%)	27 (25%)	−3%
Neighborhood pattern and design (NPD)	39 (37%)	44 (40%)	+3%
Green infrastructure and buildings (GIB)	31 (29%)	29 (26%)	−3%
Innovation and design processes (IDP)	6 (6%)	6 (5%)	−1%
Regional priority credit (RP)	Not applicable	4 (4%)	+4%
Total	106	110	

It should be noted that although significant changes have been made in LEED ND 2009, many new problems have been identified. For example, it is found that the prerequisite that at least one LEED-certified building should be in the neighborhood development project seems too restrictive and commercial by excluding the use of other internationally recognized green building rating systems [19]. In addition, LEED ND does not consider the size of the development. It may be difficult for large projects to achieve compact development, when compared with small projects [20]. Single buildings which are located in already well developed urban areas can achieve better ratings [20]. In order to fully understand how the rating system works, and more importantly to continually improve the rating system to be more technically robust and easier to use, a broader and comprehensive analysis of the performance of certified projects is needed [21].

3. Research Method

3.1. Samples

This study aimed to include all LEED ND 2009 certified projects. As only 10 projects were certified by LEED ND 2009, this study included all pre-certified LEED ND 2009 plans. The pre-certification could be obtained if 100% of the project's floor area has been fully entitled by public authorities [22]. There were 208 plans which were registered in the directory, which can be accessed from: http://www.usgbc.org/projects/neighborhood-development. However, as many projects were only registered, the scorecards which recorded the credit achievement of these projects were not available. In the 208 projects, 55 projects were certified with detailed scorecards at the time of this study (October 2017). These projects were therefore selected as the sample of this study. It should be noted that the sample size was relatively small and may affect the accuracy of the results. We adopted two strategies to reduce the impact of a small sample size. Any omission in a small sample size can affect the results significantly. The sample therefore contains all LEED ND certified plans listed in the USGBC project directory at the time of the study. In addition, non-parametric tests were adopted because such test have fewer assumptions when compared to parametric tests.

3.2. Data Collection and Analysis

The USGBC project directory was used as the main source of data. The performance of certified projects, including the geographical location, certification levels (from Certified to Platinum), certification date, and credit allocation, were recorded into an excel spreadsheet.

The means and standard deviations of the points obtained by LEED ND 2009 certified projects in all assessment categories were calculated. The normality of the data was checked using the

Kolmogorov-Smirnov test. The null hypothesis was that the data has no significant difference from a normal distribution. If the p value is less than 0.05, the null hypothesis could be rejected, indicating that the data has significant difference from a normal distribution, that is, the data is not normally distributed. The result of the Kolmogorov-Smirnov test is shown in Table 2. As can be seen, the credit allocations of three major categories of assessment are not normal. In addition, the sample size was not ideal for a parametric test. Based on these reasons, non-parametric tests were adopted.

Table 2. The Kolmogorov-Smirnov test result of all LEED ND 2009 certified projects.

LEED–ND 2009 Credits	Kolmogorov-Smirnov Test		
	df	**Sig.**	**Finding**
SSL	55	0.036	Not normally distributed
NPD	55	0.200	Normally distributed
GIB	55	0.080	Normally distributed
IDP	55	0.000	Not normally distributed
RP	55	0.000	Not normally distributed

A number of statistical tests were also adopted in this study. The percentage of achievement (PoA), an indicator representing the frequency of obtaining the assessment credit, was adopted in this study to compare the performance on various assessment credits, which may have varied total points. The PoA was calculated using the following equation:

$$\text{PoA} = \frac{\text{Points achieved}}{\text{Total points}} \times 100\% \quad (1)$$

In addition, the Kruskal Wallis test, as a non-parametric method to compare the underlying shapes of two or more independent samples, was adopted to help identify whether the project performance of different certification levels varied. The null hypothesis was that the two or more samples had the same average (median) [23]. The alternative hypothesis was that one of the independent samples had a different shape, if the p-value was less than 0.05. The test was adopted to evaluate the performance of LEED ND projects under different certification levels and in different countries.

A Generalized Additive Model (GAM), as a non-parametric regression model to investigate the contribution of explanatory variables, was adopted to help identify the comparative importance of all assessment criteria in the rating system. The equation used in the GAM is:

$$y = \beta_0 + \sum_{i=1}^{m} f_i(x_i) + \varepsilon \quad (2)$$

where y is the total credits obtained; β_0 is a constant coefficient; x_i $(i = 1, \ldots, m)$ are explanatory variables including SSL, NPD, GIB, IDP and RP; $f_i()$ represents the smooth function of variable x_i; and ε is the random error. In addition, the Spearman's correlation, which is a non-parametric correlation test, was adopted to measure the strength and direction of the relationship between two variables [24].

4. Results

4.1. Project Landscape

Table 3 summarizes the geographical location of the 55 certified plans. As can be seen from Table 3, the majority of the LEED ND 2009 certified projects are from the United States (49.1%) and China (27.3%). Compared to LEED NC, the geographical location of the certified projects has changed significantly. According to Wu et al. (2016), 81.1% of the LEED NC 2009 certified projects are located in the United States. In addition, in LEED NC 2009, only 3.7% of the certified projects are located in China. It seems that the concept of sustainable communities is highly recognized in China, indicating a significant rise of the impact of LEED ND in China. It should be also noted that LEED ND 2009

is rarely used in Europe. This is due to the significant impact of the British Research Establishment Environmental Assessment Method (BREEAM) in the European region. BREEAM for Communities was established in 2009 and later revised in 2012 to assess the sustainability of a community [25]. The scheme had 27 certified projects till August 2016.

Table 3. Geographical location of the LEED ND 2009 certified plans.

Project Location	Project Number	Percentage (%)
United States	27	49.1
China	15	27.3
Canada	5	9.1
Malaysia	3	5.5
Brazil	2	3.6
Japan	1	2.2
Morocco	1	2.2
Hong Kong	1	1.8
Total	55	100

Table 4 summarizes the number, certification level and mean credit of LEED ND 2009 certified plans. As can be seen from Table 4, Silver and Gold projects occupy the largest share, similar to the patterns found in LEED NC [2,12]. This may imply that achieving Silver and Gold may be cost-effective. Detailed case studies were conducted on the lifecycle cost of three buildings, including an elementary school, a visitor centre and a college project. It is found that the lifecycle cost of the Silver and Gold versions of the building were lower than that of the baseline case [26]. However, achieving Platinum certification is still too costly and the marketing benefit from the Platinum certification is not sufficient to attract projects to achieve this certification level [27].

Table 4. Certification levels of LEED ND 2009 certified plans.

Certification Level	No. of Projects	Percentage (%)	Mean Credit	Standard Deviation
Certified	9	16.4	43.44	3.321
Silver	14	25.5	54.43	2.409
Gold	28	50.9	63.64	4.432
Platinum	4	7.2	82.25	2.062

A detailed investigation of the credits characterized by certification levels shows that the mean credit increase from Certified to Silver, Silver to Gold and Gold to Platinum is 10.99, 9.21 and 18.61 respectively, which validates the prior assumption that achieving Platinum in LEED ND 2009 is too costly compared to Silver and Gold (see Table 5).

Table 5. The total credits obtained by LEED ND 2009 projects characterized by certification levels.

	LEED ND 2009 Certification Level			
	Certified	**Silver**	**Gold**	**Platinum**
Possible credits	40–49	50–59	60–79	80+
Mean credits	43.44	54.43	63.64	82.25
Mean credit increase to the next level	10.99	9.21	18.61	Not applicable

4.2. Credit Achievement

The overall credit achievement of all LEED ND 2009 certified plans is shown in Table 6. As can be seen from Table 6, innovation and design process is the mostly awarded category in LEED ND 2009, with projects achieving an average of 71.82% in IDP. In accordance with previous studies, it appears that IDP is a category that can be easily awarded in either LEED green building rating (e.g., LEED v2.2 and LEED v3) or LEED green neighborhood rating (LEED ND) [2,13].

Table 6. The mean score and percentage of achievement (PoA) of each assessment category.

Assessment Category	Mean Score	Total Score	Percentage (%)
SSL	17.44	27	64.58
NPD	24.91	44	56.61
GIB	10.80	29	37.24
IDP	4.31	6	71.82
RP	1.89	2	47.27

Notes: SSL = Smart location and linkage; NPD = Neighborhood pattern and design; GIB = Green infrastructure and buildings; IDP = Innovation and design process; RP = Regional priority credits.

One alarming finding from Table 6 is the extremely low percentage of achievement (PoA) of green infrastructure and buildings, with projects achieving only 37.24% in GIB. It is a record low PoA of the assessment categories for LEED green buildings and neighborhood development. Materials and resources in LEED NC v2.2 has the lowest PoA of 42.6%, indicating the difficulty in achieving credits in this assessment category [2]. The situation has worsened when LEED NC v3 is adopted, leading to a PoA of only 38.7% for materials and resources. Low PoA can be a significant problem for the green rating system because it indicates that the assessment credits may require large capital investment or the return on investment is not optimal [28]. As such, low PoA credits may need to be re-designed. For example, it is argued that the thresholds of construction waste management in LEED NC are too high compared with its limited benefits [29].

Table 7 shows the top 10 assessment credits with the lowest PoA values. As can be seen from Table 7, the credits with the lowest PoA include: wastewater management (6.36%), restoration of habitat or wetland (7.27%) and on-site renewable energy (7.88%). The Kruskal Wallis test also reveals that there are no significant differences between the four certification levels on these credits, except existing building reuse (GIBc5). The result shows that as the certification level rises, the performance on these low PoA credits does not improve significantly, leading to a speculation that the benefits are not adequate to attract investment in these credits. Even at the Platinum level, these credits are still rarely achieved. For example, one of the most difficult credit to achieve in LEED ND is GIBc14: wastewater management. The PoA values of wastewater management for Certified, Silver, Gold and Platinum projects are 0%, 11%, 7% and 0% respectively. Compared to LEED NC which focuses on water use reduction, LEED ND has a specific focus on the reuse of waste water, which cannot be achieved using cost effective strategies such as highly efficient tap fittings and flush fixtures. In addition, the restoration of habitat or wetland is very dependent on the site locations. The minimal threshold for achieving one point in on-site renewable energy in LEED ND is 5% instead of 1% in LEED NC. This increases the difficulty of achieving points in this credit.

Table 7. The top 10 assessment credits with the lowest PoA values.

Credit	Description	PoA (%)	Asymp. Sig.
GIBc14	Wastewater management	6.36	0.610
SLLc8	Restoration of habitat or wetlands and water bodies	7.27	0.471
GIBc11	On-site renewable energy sources	7.88	0.506
GIBc10	Solar orientation	10.91	0.563
GIBc5	Existing building reuse	12.72	0.048
NPDc8	Transportation demand management	13.63	0.503
GIBc12	District heating and cooling	14.55	0.198
GIBc6	Historic resource preservation and adaptive use	16.36	0.231
GIBc17	Light pollution reduction	18.18	0.094
NPDc6	Street network	21.82	0.137

On the other hand, Table 8 shows the top 10 credits with the highest PoA values. As can be seen in Table 8, the credits with highest PoA values include LEED accredited professional (100.00%), site design for habitat conservation (92.73%) and access to civic and public space (90.09%). The pilot version of LEED neighborhood development places too much emphasis on location-sensitive criteria, such as access to civic and public space, and access to recreation facilities [9]. As such, a number of

projects have achieved higher certification levels (Silver and Gold) even though their performance in terms of green building technologies is very limited. For example, one project has obtained Gold certification level while only achieving 2 credits in green building technologies (out of 29). A detailed investigation of these 10 credits shows that there are significant differences between the mean values of SSLc3 and NPDc2 across different certification levels. Projects that have higher certification levels perform better in selecting locations with reduced automobile dependence (SSLc3) and using compact development (NPDc2).

Table 8. The top 10 assessment credits with the highest PoA values.

Credit	Description	PoA (%)	Asymp. Sig.
IDc2	LEED accredited professional	100.00	1.000
SLLc7	Site design for habitat or wetland and water body conservation	92.73	0.130
NPDc9	Access to civic and public space	89.09	0.192
SSLc3	Locations with reduced automobile dependence	88.31	0.000
NPDc10	Access to recreation facilities	87.27	0.218
IDc1	Innovation and exemplary performance	84.09	0.061
NPDc2	Compact development	83.94	0.003
SLLc6	Steep slope protection	78.18	0.493
NPDc14	Tree-lined and shaded streets	78.18	0.393
GIBc16	Solid waste management infrastructure	76.36	0.965

4.3. Predictors of LEED ND

In addition to the above investigation, a generalized additive model was developed to evaluate the predictors of LEED ND rating. The results are shown in Table 9. The most important predictors of LEED ND are neighborhood pattern and design (42.98%), smart location and linkage (28.60%), as well as green infrastructure and buildings (23.91%). In addition, the results of the Spearman correlation test of each assessment credit and the total points are shown in Table 10.

Table 9. The predictors of LEED ND rating using the Generalized Additive Model (GAM).

Predictors of LEED ND	Deviance Explained (%)
NPD	42.98
SSL	28.60
GIB	23.91
RP	2.51
IDP	2.00

Table 10. The results of the Spearman correlation test of each assessment credit and the total points.

Credits	Correlation Coefficient	Significance	Credits	Correlation Coefficient	Significance	Credits	Correlation Coefficient	Significance
SSLc1	0.456 **	0.000	NPDc1	0.442 **	0.001	GIBc1	0.343 *	0.010
SSLc2	−0.102	0.459	NPDc2	0.443 **	0.001	GIBc2	0.251	0.064
SSLc3	0.569 **	0.000	NPDc3	0.412 **	0.002	GIBc3	0.188	0.170
SSLc4	0.154	0.262	NPDc4	0.169	0.219	GIBc4	0.322 *	0.017
SSLc5	0.152	0.268	NPDc5	0.310 *	0.021	GIBc5	0.098	0.476
SSLc6	0.017	0.904	NPDc6	0.357 **	0.008	GIBc6	0.363 **	0.006
SSLc7	0.024	0.860	NPDc7	0.161	0.240	GIBc7	0.103	0.456
SSLc8	0.064	0.642	NPDc8	0.195	0.154	GIBc8	0.192	0.160
SSLc9	0.350 **	0.009	NPDc9	0.322 *	0.017	GIBc9	0.070	0.611
			NPDc10	0.236	0.083	GIBc10	0.068	0.621
			NPDc11	0.193	0.158	GIBc11	0.149	0.277
			NPDc12	0.215	0.115	GIBc12	0.176	0.200
			NPDc13	0.100	0.470	GIBc13	0.197	0.149
			NPDc14	0.167	0.223	GIBc14	0.050	0.716
			NPDc15	0.320 *	0.017	GIBc15	0.134	0.329
						GIBc16	0.092	0.505
						GIBc17	−0.165	0.229

Notes: ** Correlation is significant at the 0.01 level. * Correlation is significant at the 0.05 level.

The single most important factor in predicting the LEED ND certification level is neighborhood pattern and design, which centers on neighborhood-level physical planning and design concepts [9]. In NPD, five assessment credits, including walkable street (NPDc1), compact development (NPDc2), mixed-use neighborhood centers (NPDc3), street network (NPDc6) and access to civil and public space (NPDc9) have significant correlation with the total scores, indicating that higher scores in these credits will normally lead to higher total scores. Similarly, three assessment credits in smart location and linkage, including preferred location (SSLc1), locations with reduced automobile dependence (SSLc3) and long-term conservation management of habitat (SSLc9) are found to have significant correlation with the total scores. In green infrastructure and buildings, only three assessment credits, including certified green building (GIBc1), water efficient landscaping (GIBc4), and historic resource preservation (GIBc6), are found to have significant correlation with the total scores.

The results of a follow-up Kruskal Wallis test on these significantly correlated assessment credits with certification levels are shown in Table 11. The results show that although these assessment credits are strongly correlated with the total scores, only five assessment credits, including compact development (NPDc2), mixed-use neighborhood centers (NPDc3), preferred location (SSLc1), reduced automobile dependence (SSLc3) and water efficient landscaping (GIBc4) can help achieve higher certification levels. It appears that, in the current LEED ND rating system, developers should choose to aim these assessment credits in order to achieve higher certification levels. This may suggest a satisfactory level of benefit-cost ratio of these credits.

Table 11. The results of the Kruskal Wallist test of assessment credits characterized by certification levels.

Assessment Credits	Asymp. Sig.	Assessment Credits	Asymp. Sig.
NPDc1	0.046	SSLc1	0.007 *
NPDc2	0.003 *	SSLc3	0.000 *
NPDc3	0.018 *	SSLc9	0.104
NPDc6	0.137		
NPDc9	0.192	GIBc1	0.063
		GIBc4	0.041 *
		GIBc6	0.231

* means that difference is significant at 0.05 level.

5. Discussion

5.1. Green Neighborhood Development and Green Building

Given the large scale of neighborhood development, sustainable neighborhood development is an emerging research area of sustainability evaluation and assessment [8,30]. Instead of focusing on the performance of a single building, the performance of neighborhood development, which is considered as the fundamental building block of a city, should be prioritized [31]. As such, it is necessary and important to understand the differences between green neighborhood development and green building, as demonstrated in the rating systems.

The results show that a major difference between green neighborhood development and green building is the significantly different order of influence of the main assessment criteria, which represent the priority of the rating systems. Energy & atmosphere, indoor environmental quality and sustainable sites are the most important predictors in the LEED NC 2009, a globally recognized green building rating system [12]. The deviance explained by these three factors are 47.43%, 17.88% and 15.75% respectively [12]. It appears that the current focus of green building is to improve the energy performance and indoor environmental quality of the building and select an appropriate site with adequate transportation access. On the other hand, green neighborhood development assessment has a completely different priority, focusing on neighborhood pattern design (42.98%) and smart location and linkage (28.60%). Green infrastructure and building has relatively limited impact in the current rating system, although it is the second largest assessment criteria in terms of total scores. The underlying

definitions and design processes of green neighborhood development and green buildings are quite different based on previous studies [14]. The concept of green building has now been widely accepted to address the growing market demand for environmental sustainability in the building industry [14]. As such, the evaluation is mainly from an environmental perspective, which is often criticized because sustainability covers the triple bottom line, including economic, social and environmental criteria [32]. On the other hand, sustainable neighborhood design centers on the development of community, which is a distinctly different level from buildings in urban development and has its own characteristics, which may include accessibility and land-use diversity [33,34]. It appears that the social aspect of sustainability has been improved from green building to green neighborhood development by introducing new assessment credits, including community connectivity and involvement.

In addition, as environmental sustainability plays a significant role in promoting green building and community, it is also useful to investigate the performance of green buildings and neighborhoods on environmental sustainability criteria. The assessment credits related to green building performance in LEED ND and LEED NC are re-aligned and the PoA of these credits are compared. The credits with high and low PoA values are shown in Table 12.

Table 12. The comparison of environmental sustainability criteria between LEED ND and Leadership in Energy and Environmental Design for New Construction (LEED NC).

Green Neighborhood Development (LEED ND 2009)			Green Building (LEED NC 2009)		
Credit No.	**Credits with High PoA Values**	**PoA (%)**	**Credit No.**	**Credit**	**PoA (%)**
GIBc9	Heat island reduction	76.36	SSc7.1	Heat island reduction—nonroof	51.36
			SSc7.2	Heat island reduction—roof	78.55
GIBc16	Solid waste management	76.36	MRc2	Construction waste management	83.04
GIBc4	Water efficient landscaping	70.91	WEc1	Water efficient landscaping	72.22
GIBc13	Infrastructure energy efficiency	70.91	New credit and no equivalent credit in LEED NC 2009		
Credit No.	**Credits with Low PoA Values**	**PoA (%)**	**Credit No.**	**Credit**	**PoA (%)**
GIBc14	Wastewater management	6.36	WEc2	Innovative wastewater technologies	19.95
GIBc11	On-site renewable energy	7.88	EAc2	On-site renewable energy	16.68
GIBc10	Solar orientation	10.91	New credit and no equivalent credit in LEED NC 2009		
GIBc5	Existing building reuse	12.73	MRc1.1	Building reuse—existing walls, floors and roof	14.49
			MRc1.2	Building reuse—interior nonstructural elements	2.81
GIBc12	District heating and cooling	14.55	New credit and no equivalent credit in LEED NC 2009		
GIBc6	Historic resource preservation	16.36	New credit and no equivalent credit in LEED NC 2009		
GIBc17	Light pollution reduction	18.18	SSc8	Light pollution	23.62

Moving from green building assessment to green neighborhood development assessment, the difficulty in applying building reuse, wastewater management technologies and renewable energy has not been improved. Building reuse, wastewater treatment and on-site renewable energy are the credits with lowest achievement rates (10%, 11% and 15% respectively) [21]. A comprehensive analysis of 3416 LEED NC 2009 certified projects reveals that the PoA values of building reuse, wastewater management and renewable energy are 14.49% (exterior)/2.81% (interior), 19.95% and 16.68% respectively [12]. The life cycle energy analysis is adopted to investigate the energy saving of building reuse and found that number of credits for building reuse in LEED 2009 is not a fair recognition of its potential energy savings [35]. This unfair recognition has not been improved in the neighborhood assessment with the PoA values of wastewater management and on-site renewable energy dropped significantly. On the other hand, green neighborhood development and green building share some commonly achieved assessment credits, including heat island reduction, solid waste management and water efficiency landscaping.

5.2. The Current LEED ND Rating System

The results also indicate that the LEED ND rating system may have unbalanced allocation of scores to the three aspects of sustainability, including economic, social and environmental sustainability.

In order to investigate the allocation pattern, each assessment credit of LEED ND 2009 is classified into its significantly relevant sustainability category/categories. Only the credits that belong to the assessment areas of SLL, NPD and GIB are investigated, because no clear assessment credits are presented in the assessment category of innovation and design processes and regional priority credits vary significantly for projects with different zip codes. A summary of the investigation is shown in Table 13. As indicated in Table 13, the majority of the credits are associated with environmental and social sustainability. Specifically, 10 and 20 assessment credits are grouped into the "social-environmental sustainability" and "environmental sustainability" respectively, accounting for 36% and 32% of total credit points. The economic dimension of sustainability, to a certain extent, has been ignored. The value of economy, social and environmental points in LEED NC is approximately 0%, 12% and 82% respectively, with the remaining points being procedural and extra related [36]. This issue is not appropriately addressed in current LEED ND rating. It should also be noted that economic performance is also important to investigate the cost-benefit ratio of each credit and importance of achieving economic sustainability should not be overlooked. The lack of an appropriate assessment of economic sustainability is a common issue of popular assessment systems such as BREEAM for Communities and CASBEE for Urban Development [37].

Table 13. Distribution of LEED ND 2009 credits across various sustainability categories.

Category	No. of Assessment Credits				Credit Points	
	SLL	NPD	GIB	Total	Total	Percentage (%)
Economic sustainability	0	0	0	0	0	0
Social sustainability	0	7	0	7	11	11
Environmental sustainability	4	0	16	20	32	32
Economic-social sustainability	1	2	0	3	11	11
Economic-environmental sustainability	0	0	0	0	0	0
Social-environmental sustainability	3	6	1	10	36	36
Economic-social-environmental sustainability	1	0	0	1	10	10
Total	9	15	17	41	100	100

It should be noted that the lack of assessing economic sustainability indicates an unbalanced sustainability assessment of LEED ND 2009, which is inconsistent with the current consensus about sustainability assessment through a pluralistic method [38]. One reason for the unbalanced sustainability assessment is that there is a lack of equal knowledge on the measurement of the different dimensions of sustainability, and also limited knowledge on both sustainability and sustainable assessment [39,40]. Additionally, the limited involvement of stakeholders in the tool development, which hinders the expression of different concerns and expectations, is another reason [39,41].

The unbalanced sustainability assessment in LEED ND 2009 can result in several issues. It has the possibility to induce stakeholders to believe that sustainability can be achieved by working at the margins instead of integrating its different pillars, thus leading to the exploitation of advantages in rating [39]. For instance, it is found that projects aiming to achieve the certification of LEED ND gold or platinum are more likely to incorporate environmental sustainability features into their development than LEED ND Certified or Silver projects [9]. In addition, as economic sustainability has not attracted enough attention, some certified projects can still be considered unsustainable in practice as they can hardly meet the requirements of those who are sensitive to economic-related factors, such as low-income households. Economic features (e.g., local business) are critical for the development of sustainable neighborhood, and thus a sustainability assessment tool should take it into account to ensure a comprehensive assessment [38].

6. Conclusions and Policy Implications

Instead of focusing on the performance of single buildings, sustainable neighborhood assessment focuses on another major building block of city, which is the neighborhood. Since its inception, sustainable neighborhood assessment has attracted much attention over the years because it is widely believed that sustainability in single buildings is not adequate to achieve the general sustainability goals for the whole society. Following such recognition, sustainable community assessment has become a popular tool to assist decision making and LEED ND is one of the widely adopted sustainable community assessment systems. As the assessment system has only been available since 2007, a comprehensive analysis of the performance of certified projects is needed for practitioners to understand and prepare for LEED ND certification and for regulatory bodies, such as USGBC, to improve the current rating system.

One major contribution of this study to the body of knowledge is the reveal of the credit achievement pattern of LEED ND certified projects on a few indicators, including project landscape, percentage of achievement and predictors. It is found that LEED ND has a higher global impact when compared to LEED NC. As a new initiative, LEED ND has its marketing benefits, leading to a relatively low or no positive skewness of the credits achieved. In addition, the most commonly achieved credits include using LEED accredited professional site design for habitat conservation and access to civic and public space. On the other hand, the least commonly achieved assessment credits include wastewater management, restoration of habitat or wetland and on-site renewable energy. The predictors of LEED ND, ranked by their order of influence, are neighborhood pattern and design, smart location and linkage, green infrastructure and buildings, regional priority credits, as well as innovation and design process.

Another contribution of this study is the comparison between green buildings and green neighborhoods based on their relevant rating systems. It is found that while environmental sustainability, in terms of energy & atmosphere and indoor environmental quality, represents the single largest assessment category, its contribution towards sustainable communities is relatively low. However, the achievement of environmental sustainability criteria across green buildings and green communities has similar patterns where the application of building reuse, wastewater management technologies and renewable energy remains difficult in both rating systems. On the other hand, a smooth transition from green buildings to green communities has been identified in credits including heat island reduction, solid waste management and water efficiency landscaping.

This study has several limitations. It offers a preliminary investigation of the differences between LEED ND and LEED NC. The detailed assessment of each credit is not provided in the paper. It is recommended that a life cycle assessment study should be conducted to evaluate the environmental impacts of each assessment credit. The cost benefit ratio of the assessment credits can then be investigated, guiding the reallocation of points to the assessment credits.

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