LEED-CI V3 AND V4 GOLD PROJECTS FOR OFFICE SPACES: THE DIFFERENCE BETWEEN SHANGHAI AND CALIFORNIA

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ABSTRACT

The Leadership in Energy and Environmental Design (LEED) rating system is currently progressing from version 3 (V3) to 4 (V4) with the aim of reducing environmental damage in the global construction sector. The LEED Commercial Interiors (LEED-CI) subsystem is widely used for office spaces, particularly in Shanghai and California. Comparing Shanghai and California in terms of LEED-CI projects can shed light on the ability of the LEED-CI subsystem to adapt to local green building standards and local environmental conditions. The aim of this study was to assess the difference between V3 and V4 LEED-CI Gold office projects using a comparison between Shanghai and California. The US Green Building Council and the Green Building Information Gateway databases were used to source LEED-CI V3 and V4 Gold office projects. The natural logarithm of the odds ratio and Fisher's exact 2 × 2 tests with a mid p-value were used to evaluate the binary data, while the Cliff's δ and exact Wilcoxon–Mann–Whitney tests were used to evaluate the ordinal data. The results show no difference between Shanghai and California in terms of LEED-CI V3 Gold office projects in the five main LEED-CI categories. The shift from V3 to V4 LEED-CI Gold office projects is increasing the difference between Shanghai and California in terms of the following LEED-CI categories: location and transportation, water efficiency, energy and atmosphere, and materials and resources. Therefore, as compared to V3, V4 for LEED-CI Gold office projects demonstrated greater adaptability to local green building standards and environmental conditions.

KEYWORDS

LEED-CI V3; LEED-CI V4; Shanghai; California

1. INTRODUCTION

The Leadership in Energy and Environmental Design (LEED) rating system is one of the most well-known rating systems for green building certification. LEED covers various types of buildings, such as New Construction and Major Renovations (LEED-NC), Commercial Interiors (LEED-CI), Existing Buildings (LEED-EB), Core and Shell Development (LEED-C&S), among others. LEED was launched in the US in 1998 by the US Green Building Council

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(USGBC) (Ade and Rehm, 2020) and, since that time, has developed through a series of versions and improvements. For example, the version history specific to LEED-NC is as follows: v2.0 in 2000, v2.1 in 2002, v2.2 in 2005, v3 in 2009, and v4 in 2013.

LEED contains five main categories: sustainable sites (SS)/location and transportation (LT); water efficiency (WE); energy and atmosphere (EA); materials and resources (MR); and indoor environmental quality (EQ); and two additional categories: innovation and design process (ID) and regional priority (RP). Each of these categories contains one or several credits with relevant requirements and points to be awarded. The number of points awarded depends on the importance of the sustainability issue covered in a credit. The credits' weighting system initially aimed to cover US-relevant environmental concerns. LEED suggests four certification levels: Certified (40–49 points); Silver (50–59 points); Gold (60–79 points); and Platinum (80 points and above).

Originally, LEED was designed for the US. However, the LEED rating system is currently used in many countries (Wu et al., 2017). For example, LEED is widely used across Europe, in countries such as Spain, Italy, Turkey, Finland, and Sweden (Głuszak, 2015). However, Faulconbridge (2015) demonstrated that a credit weighing system developed for the US does not fully take into account the "sensitivity of sustainable construction models" in foreign countries. Suzer (2015) believed that ". . . the latest version of LEED V4 still does not provide a flexible framework or adaptable category weights that allow the customization of the system" for local conditions. The LEED challenge today is to be adaptable to different environmental conditions and green building standards. LEED-CI V4 Gold office projects are the most popular green building projects in big cities in China and California, as well as in other states in the US (Pushkar 2020). Therefore, this study focuses on office-type buildings in the megacity of Shanghai and California in order to study the adaptability of LEED-CI to local environmental conditions and building standards. We focused on these two places to minimize the impact that uncontrollable factors had in terms of consistency in the LEED-CI scorecard in each group.

2. LITERATURE REVIEW

In studies related to the appropriateness of LEED in non-US building markets, Pushkar (2018a, 2018b), Wu et al. (2018), and Pham et al. (2020) reported examples of the successful adaptive use of LEED in different countries around the world. Pushkar (2018a) noted different strategies for LEED certification in two different European countries (Finland and Sweden) related to the WE, EA, MR, and EQ categories. In contrast, in three Mediterranean countries (Turkey, Spain, and Italy), which share similar regional environmental problems, similar goals regarding the SS, MR, and EQ categories were reported (Pushkar 2018b). In addition, in LEED projects certified in the US, China, Turkey, and Brazil, Wu et al. (2018) revealed different country-relevant strategies for 21 credits under alternative compliance paths (for example, the EA category showed superior performance in the US as compared to the other countries, whereas China was the leader in terms of SS and WE performance). Pham et al. (2020) studied LEED-NC V3 Silver, Gold, and Platinum projects certified in Vietnam, which is characterized by a humid tropical climate, and concluded that the majority of SS, WE, and EQ credits worked well.

LEED also serves as a guiding template for suggesting appropriate building materials, approaches, and techniques for building renovations in different countries. For example, the LEED-NC V3 certification was used to improve the resilience of schools in northern Italy

(Dall'O' et al. 2013). The Gold LEED-EB V3 certification was applied to Chow Yei Ching (CYC) University building in Hong Kong during its renovation with the aim of reducing energy consumption (Sun et al. 2018). LEED-EB V4 was used in the renovation of Ca' Rezzonico in Italy in order to promote energy saving, water saving and control, and light metering (Mazzola et al. 2019).

The aforementioned studies on non-US LEED certification projects only explored projects following the LEED V3 certification (Pushkar 2018a; 2018b; Wu et al. 2018; Pham et al. 2020). However, LEED V4 (the current version) differs from LEED V3 (the previous version) in several respects. This is the case for all LEED systems, including LEED-CI. Thus, in LEED-CI V4, the SS category from LEED-CI V3 was transformed into the LT category. In addition, a new category: Integrative Process (IP), was added to LEED-CI V4. Moreover, the categories of LEED-CI V3 and V4 have different numbers of maximum possible points. LEED-CI V3 has an SS category with 21 points, a WE category with 11 points, an EA category with 37 points, an MR category with 14 points, and an EQ category with 17 points (LEED-CI V3 2009); whereas LEED-CI V4 has an IP category with 2 points, an LT category with 18 points, an SS category with 10 points, a WE category with 12 points, an EA category with 38 points, an MR category with 13 points, and an EQ category with 17 points (LEED-CI V4 2014).

Thus, in order to obtain accurate evidence concerning the adaptability of V4 as compared with V3 for LEED-CI projects, comparisons between homogeneous groups, such as one megacity (e.g., Shanghai) and one US state (e.g., California), are necessary. In this context, Shanghai suffers from a severe water deficit (Zhao et al., 2015), while California adheres to strict energy efficiency standards (Adekanye et al., 2020). Thus, a comparison of LED-CI projects in Shanghai and California should show that the WE category performs better in Shanghai than in California, while the EA category performs better in California than in Shanghai. Shanghai and California have yet to be compared in terms of LEED-CI V3 and V4 Gold projects for office space.

The aim of this study was to empirically prove that the transition from V3 to V4 in LEED-CI Gold office projects is useful for solving local environmental problems. Our approach involved analyzing the differences between Shanghai and California.

3. METHODS

3.1 Research Design Principles

To reduce the influence of unknown factors, the LEED projects had to belong to one rating system, one certification level, one geographical location, and one certified date (Pushkar, 2018c; Pushkar and Verbitsky, 2018, 2019a, 2019b). Moreover, the LEED projects were randomly selected where possible.

3.2 Collection data

The LEED-CI Gold projects for office spaces were sourced from the following two databases: the USGBC and the Green Building Information Gateway (GBIG). The USGBC database was used to collect the credit achievements in LEED-CI V3 and V4 Gold projects, and the GBIG database was used to collect LEED-CI Gold projects for office spaces only.

In order to compare V4 and V3 LEED-CI Gold projects for office spaces, we chose Shanghai and California as, within these two groups, the influence of uncontrollable factors can be minimized. In Shanghai, 38 LEED-CI V4 Gold office projects were identified. Consequently, 38 Shanghai-LEED-CI V3 Gold office projects were randomly selected. In California, 21 LEED-CI V4 Gold office projects from seven sites were identified. Consequently, 21 California-LEED-CI V3 Gold projects from the same seven sites were randomly selected. California was represented by the following seven cities: San Francisco (11), Sunnyvale (5), Santa Monica (1), Los Angeles (1), Rancho Cordova (1), Fremont (1), and Menlo Park (1); the numbers in brackets represent the number of projects at that location.

3.3 Sample size

The minimal sample size for the Wilcoxon–Mann–Whitney (WMW) test in a nonexperimental study is as follows: if $n_1 = 5$, then $n_2 > 10$ (Mundry and Fischer, 1998). The minimal sample size for the Fisher's exact 2 × 2 test with a two-tailed Lancaster's mid-P-value is $n_1 = n_2 = 3$ (Routledge, 1992). In the present study, the sample size was $n_1 = 21$ and $n_2 = 38$. The WMW statistic depends solely on the total number of observations in the two groups ($N = n_1 + n_2$) (Bergmann et al., 2000), and the WMW test can be used for unbalanced groups (Mandry and Fisher, 1998). Consequently, both the WMW test and Fisher's exact 2 × 2 test were acceptable for use in the present study.

3.4 Statistical analysis

Because the assumption of normality for the LEED data (i.e., the achieved points from the LEED scorecard according to the USGBC database) was not met (Chi et al., 2020, Table 2, p. 4) and the LEED data related to discrete interval variables had relatively few values, we used the median and the 25th–75th centiles for descriptive statistics and the Cliff's δ effect size (Cliff, 1993) and the exact WMW (Bergmann et al., 2000) tests for inferential statistics. If the LEED data had binary ("0 or 1") variables, we used the natural logarithm of the odds ratio ($\ln\theta$) (Bland and Altman, 2000) instead of Cliff's δ, and Fisher's exact 2 × 2 test with a two-tailed Lancaster's mid-P-value (Lancaster 1961) instead of the exact WMW test.

3.5 Effect size interpretation

Cliff's δ ranged between –1 and +1. Positive (+) values indicate that Group 1 is larger than Group 2; 0 indicates equality or overlap; and negative (-) values indicate that Group 2 is larger than Group 1 (Cliff, 1993). According to Romano et al. (2006), the effect size is considered to be: (i) negligible if $|\delta| < 0.147$; (ii) small if $0.147 \leq |\delta| < 0.33$; (iii) medium if $0.33 \leq |\delta| < 0.474$; and (iv) large if $|\delta| > 0.474$.

$\ln\theta$ can take any value and has an approximately normal distribution (Bland and Altman, 2000). The degree of association between binary outcomes was adapted from the study by Chen et al. (2010). The effect size thresholds of the absolute $\ln\theta$($|\ln\theta|$) were considered to be 0.51 (small), 1.24 (medium), and 1.90 (large).

3.6 P-value interpretation

Following Hurlbert and Lombardi (2009), the P-values were evaluated according to three-valued logic: it appears to be positive (i.e., there appears to be a difference between Shanghai and California), it appears to be negative (i.e., there does not appear to be a difference between Shanghai and California), or judgment is suspended (regarding the difference between Shanghai and California).

4. RESULTS

4.1 LEED categories

The results show no difference between Shanghai and California in terms of LEED-CI V3 Gold office projects in the five main LEED-CI categories. The shift from V3 to V4 LEED-CI Gold office projects is increasing the difference between Shanghai and California in terms of the following LEED-CI categories: LT, WE, EA, and MR (Table 1).

In addition, the number of categories that showed different results was higher in LEED-CI V4 projects than in LEED-CI V3 projects. In the LEED-CI V3 certified projects, Shanghai emphasized the RP category. However, in the LEED-CI V4 certified projects, Shanghai emphasized the LT and WE categories, whereas California emphasized the EA and MR categories. In all these categories, the differences between Shanghai and California appeared to be positive. The results from other categories of LEED-CI V3 and LEED-CI V4 were similar in both Shanghai and California, i.e., differences between Shanghai and California appeared to be negative, or the judgment regarding the differences between Shanghai and California was suspended.

Despite such differences in the strategies of Shanghai and California for achieving LEED-CI V3 and LEED-CI V4 Gold certifications, the total points awarded were similar in both Shanghai and California. In the LEED-CI V3 and LEED V4 projects, the differences between Shanghai and California appeared to be negative.

4.2 LEED credits

4.2.1 Sustainable Site and Location and Transportation

Table 2 shows the descriptive and inferential statistics for the SS credits of the LEED-CI V3 and the LT credits of the LEED-CI V4 Gold projects. For the SS credits, only the SSc3.3 Alternative transportation category, parking availability, demonstrated superior performance in Shanghai as compared with California, and the difference between Shanghai and California appeared to be positive, whereas all other credits performed similarly in Shanghai and California, and the difference between Shanghai and California appeared to be negative.

For the LT credits, three of the four credits—LTc2 Surrounding density and diverse uses, LTc3 Access to quality transit, and LTc5 Reduced parking footprint—performed better in Shanghai than in California and the difference between Shanghai and California appeared to be positive, whereas only LTc4 Bicycle facilities performed similarly in both Shanghai and California, and the difference between Shanghai and California appeared to be negative.

4.2.2 Energy and Atmosphere

Table 3 shows the descriptive and inferential statistics for the EA credits of the LEED-CI vV3 and LEED-CI V4 Gold projects. For the LEED-CI V3 certification, only three of the seven EA credits performed differently in Shanghai and California, i.e., EAc1.2 Optimize energy performance: lighting controls and EAc1.3 Optimize energy performance: HVAC performed better in California than in Shanghai, whereas EAc3 Measurement and verification performed better in Shanghai than in California. In all these credits, the differences between Shanghai and California appeared to be positive. The other four EA credits performed similarly in both Shanghai and California, and the difference between Shanghai and California appeared to be negative, or the judgment about differences between Shanghai and California was suspended.

TABLE 1. LEED-CI V3 and LEED-CI V4 Gold categories: the difference between Shanghai and California.

Category	Max points	Median and 25th–75th centiles		δ	P
		Shanghai	California		
LEED-CIv3					
SS Sustainable Sites	21	17.0 16.0–19.0	17.0 14.0–19.0	0.18	0.2552
WE Water Efficiency	11	11.0 11.0–11.0	11.0 8.0–11.0	0.22	0.1060
EA Energy and Atmosphere	37	17.0 16.0–19.0	18.0 15.0–22.0	–0.21	0.1842
MR Materials and Resources	14	4.5 3.0–6.0	4.0 3.0–5.0	0.11	0.4985
EQ Indoor Environ. Quality	17	8.0 6.0–10.0	9.0 7.0–10.3	–0.21	0.1875
IN Innovation	6	5.0 3.0–6.0	4.0 4.0–5.3	0.09	0.5785
RP Regional Priority	4	4.0 4.0–4.0	2.0 2.0–3.0	0.79	>**0.0001**
Total	110	65.0 64.0–68.0	64.0 61.0–67.0	0.22	0.1660
LEED-CIv4					
IP Integrative Process	2	2.0 0.0–2.0	2.0 1.0–2.0	0.07	0.6575
LT Location and Transportat.	18	17.0 17.0–18.0	15.0 3.8–17.0	0.58	>**0.0001**
WE Water Efficiency	12	10.0 8.0–12.0	6.0 6.0–8.0	0.57	>**0.0001**
EA Energy and Atmosphere	38	15.0 13.0–17.0	24.0 15.8–29.0	–0.49	**0.0014**
MR Materials and Resources	13	3.5 3.0–5.0	5.0 4.0–6.0	–0.46	**0.0029**
EQ Indoor Environ. Quality	17	7.0 6.0–10.0	7.0 6.0–9.0	0.06	0.7238
IN Innovation	6	5.0 5.0–6.0	5.0 5.0–6.0	–0.17	0.2466
RP Regional Priority	4	3.0 3.0–4.0	3.0 3.0–4.0	–0.07	0.6375
Total	110	63.0 61.0–65.0	63.0 60.0–64.0	0.24	0.1305

The P-values were evaluated according to the following three-valued logic: bold font: appears to be positive; ordinal font size: appears to be negative; italic font: judgment suspended.

However, for the LEED-CI V4 certification, five of the six EA credits performed differently in Shanghai and California, i.e., EAc1 Enhanced commissioning, EAc3 Renewable energy production, EAc5 Green power and carbon offset, and EAc6 Optimized energy performance performed better in California than in Shanghai, whereas EAc4 Enhanced refrigerant

TABLE 2. LEED-CI V3 Sustainable Site (SS) and LEED-CI V4 Gold Location and Transportation (LT) credits: the difference between Shanghai and California.

Credit	Max points	Median and 25th–75th centiles		δ/lnθ	P
		Shanghai	California		
LEED-CIv3					
SSc1 Site selection	5	3.0 1.0–5.0	5.0 1.0–5.0	–0.11	0.4598
SSc2 Develop. density and community	6	6.0 6.0–6.0	6.0 6.0–6.0	0.10	0.2455
SSc3.1 AT: public transportat. access	6	6.0 6.0–6.0	6.0 6.0–6.0	0.05	0.7119
SSc3.2 AT: bicycle stor. and changing	2	0.0 0.0–2.0	0.0 0.0–2.0	–0.08	0.7383
SSc3.3 AT: parking availability	2	2.0 2.0–2.0	2.0 0.0–2.0	0.32	**0.0123**
LEED-CIv4					
LTc2 Surround. density and diverse uses	8	8.0 8.0–8.0	8.0 2.0–8.0	0.48	>**0.0001**
LTc3 Access to quality transit	7	7.0 7.0–7.0	6.0 0.0–7.0	0.52	>**0.0001**
LTc4 Bicycle facilities[1]	1	0.0 0.0–1.0	0.0 0.0–1.0	0.27	0.6802
LTc5 Reduced parking footprint	2	2.0 2.0–2.0	2.0 0.0–2.0	0.40	**0.0016**

AT—Alternative transportation
The P-values were evaluated according to the following three-valued logic: bold font: appears to be positive; ordinal font size: appears to be negative; italic font: judgment suspended.
[1]To estimate the effect size and statistical difference between Shanghai and California, the LEED-CIv4 LTc4 credit was treated using the log odds ratio (lnθ) and Fisher's exact test 2 × 2 tables with a two-tailed Lancaster's mid-P-value.

management performed better in Shanghai than in California. In all these credits, the difference between Shanghai and California appeared to be positive. Only the EAc2 Advanced energy metering credit performed similarly in both Shanghai and California, and the difference between Shanghai and California appeared to be negative.

4.2.3 Material and Resources

Table 4 shows the descriptive and inferential statistics for the MR credits of the LEED-CI V3 and LEED-CI V4 Gold projects. For the LEED-CI V3 certification, only MRc1.1 Tenant space: long-term commitment and MRc7 Certified wood demonstrated a superior performance in California as compared with Shanghai, and the MRc5 Regional materials credit demonstrated a superior performance in Shanghai compared to in California. In all these credits, the difference between Shanghai and California appeared to be positive. The other six MR credits performed similarly in both Shanghai and California, and the difference between Shanghai and California appeared to be negative.

However, for the LEED-CI V4 certification, five of the six MR credits performed differently in Shanghai and California: MRc1 Long-term commitment, MRc3 Building product

TABLE 3. LEED-CI V3 and LEED-CI V4 Gold Energy and Atmosphere (EA) credits: the difference between Shanghai and California.

Credit	Max points	Median and 25th–75th centiles		δ/lnθ	P
		Shanghai	California		
LEED-CIv3					
EAc1.1 OEP: lighting power	5	4.0 3.0–5.0	3.0 1.8–4.3	0.28	*0.0642*
EAc1.2 OEP: lighting controls	3	1.0 0.0–2.0	2.0 1.0–3.0	–0.35	**0.0264**
EAc1.3 OEP: HVAC	10	0.0 0.0–0.0	0.0 0.0–5.0	–0.28	**0.0347**
EAc1.4 OEP: equipment	4	4.0 2.0–4.0	4.0 3.8–4.0	–0.22	*0.0994*
EAc2 Enhanced commissioning	5	5.0 0.0–5.0	5.0 0.0–5.0	–0.16	0.3478
EAc3 Measurement and verificat.	5	3.0 0.0–5.0	0.0 0.0–0.8	0.54	**0.0002**
EAc4 Green power	5	5.0 0.0–5.0	5.0 5.0–5.0	–0.18	0.2587
LEED-CIv4					
EAc1 Enhanced commissioning	5	4.0 4.0–4.0	4.0 4.0–5.0	–0.31	**0.0271**
EAc2 Advanced energy metering	2	1.0 0.0–1.0	1.0 0.0–2.0	–0.12	0.5003
EAc3 Renewable energy production	3	0.0 0.0–0.0	0.0 0.0–0.5	–0.24	**0.0081**
EAc4 Enhanced refriger. manag.[1]	1	1.0 1.0–1.0	0.0 0.0–1.0	1.66	**0.0034**
EAc5 Green power and carbon offset	2	0.0 0.0–2.0	2.0 0.0–2.0	–0.33	**0.0265**
EAc6 Optimized energy performan.	25	8.0 8.0–11.0	16.0 8.0–21.0	–0.36	**0.0198**

OEP—Optimize energy performance.
The P-values were evaluated according to the following three-valued logic: bold font: appears to be positive; ordinal font size: appears to be negative; italic font: judgment suspended.
[1]To estimate the effect size and statistical difference between Shanghai and California, the LEED-CIv4 EAc4 credit was treated using the log odds ratio (lnθ) and Fisher's exact test 2 × 2 tables with a two-tailed Lancaster's mid-P-value.

disclosure and optimization (BPD and O), environmental product declarations, MRc4 BPD and O, sourcing of raw materials, and MRc5 BPD and O, material ingredients performed better in California than in Shanghai. Moreover, EAc3 Measurement and verification performed better in California than in Shanghai, and MRc6 Construction waste management performed better in Shanghai than in California. In all these credits, the difference between Shanghai and California appeared to be positive. The MRc2 Interiors life-cycle impact reduction performed similarly in both Shanghai and California, and the difference between Shanghai and California appeared to be negative.

4.2.4 Indoor Environmental Quality

Table 5 shows the descriptive and inferential statistics for the EQ credits of the LEED-CI V3 and LEED-CI V4 Gold projects. For the LEED-CIv3 certification, three EQ credits—EQc3.2

TABLE 4. LEED V3 and LEED-CI V4 Gold Materials and Resources (MR) credits: the difference between Shanghai and California.

Credit	Max points	Median and 25th–75th centiles		δ/lnθ	P
		Shanghai	California		
LEED-CIv3					
MRc1.1 Ten. Space: long-term com[1]	1	0.0 0.0–0.0	1.0 0.0–1.0	–2.18	**0.0003**
MRc1.2 Building reuse: interior el.	2	0.0 0.0–0.0	0.0 0.0–0.0	0.00	1.0000
MRc2 Construction waste management	2	2.0 0.0–2.0	2.0 2.0–2.0	–0.19	0.1427
MRc3.1 Materials reuse	2	0.0 0.0–0.0	0.0 0.0–0.0	0.00	1.0000
MRc3.2 Materials reuse: furniture[1]	1	0.0 0.0–0.0	0.0 0.0–0.0	1.51	0.1785
MRc4 Recycled content	2	1.0 1.0–2.0	1.0 1.0–2.0	0.06	0.7147
MRc5 Regional materials	2	1.0 1.0–2.0	0.0 0.0–0.0	0.77	>**0.0001**
MRc6 Rapidly renewable materials[1]	1	0.0 0.0–0.0	0.0 0.0–0.0	–0.62	0.7668
MRc7 Certified wood[1]	1	0.0 0.0–0.0	0.0 0.0–0.3	–Inf	**0.0020**
LEED-CIv4					
MRc1Long-term commitment[1]	1	0.0 0.0–1.0	1.0 0.8–1.0	–1.37	**0.0212**
MRc2 Interiors life-cycle impact reduct.	4	0.0 0.0–3.0	0.0 0.0–1.0	0.21	0.1428
MRc3 BPD&O: envir. product declarat.	2	0.0 0.0–0.0	1.0 0.8–1.0	–0.66	>**0.0001**
MRc4 BPD&O: sourcing of raw mater.	2	0.0 0.0–0.0	1.0 0.0–1.0	–0.49	**0.0003**
MRc5 BPD&O: material ingredients	2	0.0 0.0–0.0	1.0 1.0–1.0	–0.80	>**0.0001**
MRc6 Construction waste management	2	2.0 2.0–2.0	2.0 1.0–2.0	0.35	**0.0013**

The P-values were evaluated according to the following three-valued logic: bold font: appears to be positive; ordinal font size: appears to be negative; italic font: judgment suspended.
[1]To estimate the effect size and statistical difference between Shanghai and California, the LEED-CIv3 MRc1.1, MRc3.2, MRc6, and MRc7, and the LEED-CIv4 MRc1 credit were treated using the log odds ratio (lnθ) and Fisher's exact test 2 × 2 tables with a two-tailed Lancaster's mid-P-value.

Construction indoor air quality management plan: before occupancy; EQc7.2 Thermal comfort: verification; and EQc8.1 Daylight and views: daylight—performed better in Shanghai than in California, whereas five EQ credits—EQc4.4 Low-emitting materials: composite wood; EQc4.5 Low-emitting materials: systems furniture; EQc5 Indoor chemical and pollutant source control; EQc6.1 Controllability of systems: lighting; and EQc6.2 Controllability of systems: thermal comfort—performed better in California than in Shanghai. In all these credits, the difference between Shanghai and California appeared to be positive. All the other EQ credits performed similarly in both Shanghai and California, and the difference between Shanghai and California appeared to be negative, or the judgment about differences between Shanghai and California was suspended.

TABLE 5. LEED-CI V3 and LEED-CI V4 Gold indoor environmental quality (EQ) credits: the difference between Shanghai and California.

Credit	Max points	Median and 25th–75th centiles		δ/lnθ	P
		Shanghai	California		
LEED-CIv3					
EQc1 Outdoor air deliv. monitoring[1]	1	0.0 0.0–0.0	0.0 0.0–1.0	–0.25	0.6480
EQc2 Increased ventilation[1]	1	1.0 0.0–1.0	0.0 0.0–1.0	0.87	0.1314
EQc3.1 C IAQ MP: during constr.[1]	1	1.0 1.0–1.0	1.0 1.0–1.0	–Inf	0.3282
EQc3.2 C IAQ MP: before occupancy[1]	1	1.0 0.0–1.0	0.0 0.0–0.3	1.82	**0.0018**
EQc4.1 LEM: adhesives and seal.[1]	1	1.0 1.0–1.0	1.0 1.0–1.0	–0.62	0.4123
EQc4.2 LEM: paints and coat.[1]	1	1.0 1.0–1.0	1.0 1.0–1.0	0.64	0.4485
EQc4.3 LEM: flooring systems[1]	1	0.0 0.0–1.0	1.0 0.0–1.0	–1.02	*0.0808*
EQc4.4 LEM: composite wood[1]	1	0.0 0.0–0.0	1.0 0.0–1.0	–Inf	< **0.0001**
EQc4.5 LEM: systems furniture[1]	1	0.0 0.0–1.0	1.0 0.8–1.0	–1.59	**0.0105**
EQc5 IC and PS control[1]	1	0.0 0.0–0.0	0.0 0.0–1.0	–1.97	**0.0082**
EQc6.1 CS: lighting[1]	1	0.0 0.0–0.0	0.0 0.0–1.0	–1.40	**0.0342**
EQc6.2 CS: thermal comfort[1]	1	0.0 0.0–0.0	0.0 0.0–0.0	–Inf	**0.0205**
EQ7.1 Thermal comfort: design[1]	1	1.0 1.0–1.0	1.0 1.0–1.0	–Inf	0.6780
EQc7.2 Thermal comfort: verific.[1]	1	1.0 1.0–1.0	1.0 0.0–1.0	2.20	**0.0039**
EQc8.1 D&V: daylight	2	0.0 0.0–1.0	0.0 0.0–0.0	0.31	**0.0158**
EQc8.2 D&V: views[1]	1	0.0 0.0–1.0	0.0 0.0–1.0	0.04	0.8873
LEED-CIv4					
EQc1 Enhanced IAQ strategies	2	2.0 1.0–2.0	2.0 1.0–2.0	0.13	0.3714
EQc2 Low-emitting materials	3	0.0 0.0–2.0	3.0 0.8–3.0	-0.48	**0.0012**
EQc3 C IAQ MP[1]	1	1.0 1.0–1.0	1.0 1.0–1.0	Inf	0.1780
EQc4 Indoor air quality assessment	2	1.0 0.0–1.0	2.0 1.0–2.0	-0.38	**0.0073**
EQc5 Thermal comfort[1]	1	0.0 0.0–1.0	0.0 0.0–0.0	1.02	0.1158
EQc6 Interior lighting	2	1.0 0.0–1.0	0.0 0.0–1.0	0.31	**0.0391**
EQc7 Daylight	3	0.0 0.0–2.0	0.0 0.0–0.0	0.41	**0.0008**
EQc8 Quality views[1]	1	1.0 0.0–1.0	0.0 0.0–1.0	0.41	0.5053
EQc9 Acoustic performance	2	0.0 0.0–0.0	0.0 0.0–0.0	0.06	0.8060

C IAQ MR: Construction indoor air quality management plan; LEM: Low-emitting materials; IC and PS: Indoor chemical and pollutant source; CS: Controllability of systems; D&V: Daylight and views.
The P-values were evaluated according to the following three-valued logic: bold font: appears to be positive; ordinal font size: appears to be negative; italic font: judgment suspended.
[1]To estimate the effect size and statistical difference between Shanghai and California, the LEED-CIv3 and LEED-CIv4 credits were treated using the log odds ratio (lnθ) and Fisher's exact test 2 × 2 tables with a two-tailed Lancaster's mid-P-value.

For the LEED-CI V4 certification, two EQ credits—EQc2 Low-emitting materials and EQc4 Indoor air quality assessment—demonstrated a superior performance in California compared to in Shanghai, and two EQ credits—EQc6 Interior lighting and EQc7 Daylight—demonstrated a superior performance in Shanghai compared to in California. In all these credits, the difference between Shanghai and California appeared to be positive. The other eight EQ credits performed similarly in both Shanghai and California, and the difference between Shanghai and California appeared to be negative.

5. DISCUSSION

As shown, both Shanghai and California achieved a similar total number of points in the LEED-CI V3 Gold projects (medians of 65 and 64 points, respectively) and LEED-CI V4 Gold projects (medians of 63 and 63 points, respectively). However, in order to achieve these certifications, Shanghai and California used different strategies.

Shanghai performed better in the LT, WE (LEED-CI V4), and RP (LEED-CI V3) categories, whereas California performed better in the EA and MR categories. However, in LEED-CI V3, both Shanghai and California performed to a similar high standard in the SS category. SS and LT are categories with credits that can be easily implemented in highly populated cities with a highly developed public infrastructure and transportation system. The majority of California-based projects are located in highly populated cities such as San Francisco and Sunnyvale. Moreover, the SS and LT credits are particularly easy to achieve in Shanghai, which is a compact megacity with 24.15 million permanent residents (Gu et al., 2020) with, as a consequence, relatively low levels of car ownership and a good public transport network (Liang and Zhang, 2018). For this reason, Shanghai outperformed California in the LT category (LEED-CI V4 2014).

Both Shanghai and California performed well in the WE category in the LEED-CI V3 Gold projects, with 11 points (median) out of 11 points for each. However, in the LEED-CI V4 projects, Shanghai performed significantly better than California (with 10 of 12 and 6 of 12 points (median), respectively). Both Shanghai (Zhao et al., 2015) and California (https://www.globalchange.gov/browse/multimedia/water-stress-us) are located in high water stress areas. It should be noted that, although Shanghai imports 79% of its virtual water from other provinces through the delivery of water-consuming goods and services, water saving remains an urgent issue (Zhao et al., 2016). For this reason, Shanghai and California are strongly motivated to save water according to the WE Water use reduction credit, which requires reductions in water use in closets, showers, and kitchen sinks (LEED-CI V3 2009; LEED-CI V4 2014).

The EA category demonstrated a superior performance in California compared to in Shanghai in both LEED-CI V3 and LEED-CI V4. Such results were expected as it is well-known that the leadership of California employs strict energy efficiency standards and applies municipal green building policies (Simcoe and Toffel, 2014; Adekanye et al., 2020). Currently, California utilizes the strictest version of the energy national code: Energy Standard for Buildings Except Low-Rise Residential Buildings, ASHRAE 90.1-2016 (ASHRAE 90.1). Moreover, the California Energy Commission (CEC) established two statewide energy efficiency standards: Building Energy Efficiency Standards (Title 24) (which is updated on a three-year cycle) and the California Green Building Standards Code (CALGreen) (Greer et al., 2019). In contrast, Shanghai is beginning to implement strict energy efficiency standards. According to Hast et al. (2015), two green electricity and carbon emission trading pilot schemes were initiated in this megacity. However, Shanghai's green electricity pilot scheme was unsuccessful because of the high prices of the type of electricity produced by local wind farms and the unfamiliarity of the population with the environmental benefit of green electricity (Hast et al., 2015). It should be noted that similar results were presented by Wu et al. (2018) for LEED-NC V3 projects certified in China and the US. The EA category was better implemented in the US than in China.

The MR category in LEED-CI V3 demonstrated a similarly poor performance in both Shanghai and California. The poor implementation of the MR category in LEED-CI V3 and LEED-NCv3 is a well-known problem in other countries such as Spain, Italy (Pushkar 2018b), Turkey, and Brazil (Wu et.al. 2018). However, the MR category, in terms of LEED-CI V4 MR credits, was better implemented in California than in Shanghai. This is due to California's superior performance in the following four credits: MRc1, MRc3, MRc4, and MRc5. MRc3, MRc4, and MRc5 have been recently introduced in LEED-CI V4 and require LCA-based building product disclosures and optimization declarations. These guidelines are intended to inform design teams about the impact related to the amount of raw materials and embodied energy used in the product or material production process (LEED-CI V4, 2014). California's superior performance for these credits indicates that such guidelines have already been incorporated into building materials and products in the US. Regarding the Construction waste management credit, both Shanghai and California performed well in the LEED-CI V3 Gold certification. However, in the LEED-CI V4 Gold certifications, Shanghai performed better as compared with California. In this credit, somewhat different results were presented by Chi et al. (2020), who reported that the US demonstrated a superior performance as compared with China in the LEED-NC V3 Gold certification. Furthermore, they concluded that only on the Platinum level did the US and China perform to a similarly high standard in LEED-NC V3 projects.

The EQ category demonstrated that California performed better than Shanghai in LEED-CI V3, whereas in LEED-CI V4, California and Shanghai performed at a similar level. However, in terms of credit level, half of a total of 16 credits for LEED-CI V3 and half of a total of 9 credits for LEED-CI V4 demonstrated different performances in California and Shanghai. Thus, in the EQ category, half of both California and Shanghai's credits were essentially the same.

6. CONCLUSION

This study compared Shanghai and California in terms of performance in LEED-CI V3 and LEED-CI V4 projects for office spaces at the Gold level. This comparison was performed on both the category and credit levels. The following was concluded:

The Category Level: Shanghai and California employed different strategies for achieving LEED-CI Gold certification for office spaces. Shanghai demonstrated superior results as compared with California in the LT and WE categories, whereas California demonstrated superior results in the EA and MR categories. Such results were expected due to the different environmental and demographical contexts of Shanghai and California.

The Credit Level. The differentiation between Shanghai and California in the LEED-CI Gold credits increased as LEED-CI developed from V3 to V4. This tendency was revealed for most LEED-CI categories, e.g., LT, EA, and MR. The only exception was the EQ category, in which half of the total credits performed similarly in Shanghai and California for both LEED-CI versions.

On the basis of the results obtained in Shanghai and California, advancing LEED-CI from V3 to V4 provides more opportunities to highlight local environmental priorities. In

Shanghai, LEED practitioners, as a result of the advanced public transport system and severe water shortages, used the LT/WE strategy to obtain LEED-CI V4 Gold certification for office spaces. In California, LEED practitioners, as a result of the high energy efficiency standards and the available materials and resources, used the EA/MR strategy to achieve LEED-CI V4 Gold certification for office spaces. This contradicts the study by Suzer (2015), in which it was concluded that the LEED V4 system still lacks a flexible evaluation mechanism for adapting to local sustainability issues. To strengthen this assumption, it is necessary to obtain additional statistics from other countries, while taking into account the political, economic, demographic, and environmental contexts.

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