Landscape and Urban Planning 112 (2013) 121–122

Contents lists available at SciVerse ScienceDirect

Landscape and Urban Planning

journal homepage: www.elsevier.com/locate/landurbplan

Comment

Spatial variation among green building certification categories: Does place matter? A rejoinder to Pushkar

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HIGHLIGHTS

- Review of our previous work questioned our choice of methods because of dependence among categories of LEED (leadership in energy and environmental design) credits.
- We find from a conceptual analysis that the LEED categories are not internally dependent.
- We find from an empirical analysis of all awarded LEED credits that no dependency exists empirically, either.

ARTICLE INFO

Article history:
Available online 19 February 2013

Keywords:
Green buildings
LEED
ANOVA

ABSTRACT

In a comment on an earlier article (Cidell & Beata, 2009) in this journal, Pushkar (2013) critiqued our use of the one-way ANOVA test for distinguishing among different LEED (leadership in energy and environmental design) credits being earned by buildings being certified as green in different U.S. regions. Her criticism is based on dependencies existing among the categories of LEED credits. However, we argue that in both conceptual and empirical terms, such dependencies are not a concern, and therefore our original results demonstrating the importance of regional differences in green buildings should stand.

1. Introduction

We appreciate the consideration of our paper and the review of our method by Pushkar (2013). It is always good to continue the discussion of ideas, especially with the rapidly growing presence of green building activity in multiple regions of the world. Our earlier paper (Cidell & Beata, 2009) considered whether or not U.S. regional geography mattered in the actual credits achieved by LEED-certified buildings as of December 2007: were some categories of credits more likely to be achieved in some EPA-designated regions of the US than others? We asked the same question with regard to credits that one might consider especially likely to be geographically dependent, such as conserving water or redeveloping brownfields. We found some slight differences among regions, specifically that the central third of the country was significantly less likely to have green buildings than the coasts based on ANOVA and *t*-test analysis. We also found through the calculation of location quotients that three categories of LEED credits, namely sustainable sites (SS), water efficiency (WE), and energy and atmosphere (EA), exhibited greater variation across regions than did materials and resources (MR), indoor environmental quality (IEQ), and innovation and design (ID). Since the first three categories were more likely to be based on the physical geography of the region, we concluded that there is regional variation in the use of LEED credits and that what we termed spatially specific credits varied even more.

Pushkar's objection to our original paper was in the choice of our method. Specifically, she argued that "the correlated nature of the LEED categories are a result of dependencies in the calculation of LEED credits from different LEED categories" (Pushkar, 2013, p. 1). Based on this argument, we should not have used an ANOVA test, which assumes independence among categories, but rather a Wilcoxon signed rank test. In her analysis using Wilcoxon, she found that "the IEQ category was the most preferable category for the LEED projects under consideration" (Pushkar, 2013, p. 2), which is one of the categories we determined to be non-spatially specific.

In this rejoinder, we argue that the LEED categories are *not*, in fact, dependent on each other, nor are they correlated. Therefore, our original method was appropriate, and our results should stand as written. We base this on both the conceptual relationship among LEED credits and the observed, empirical relationship among LEED credits.

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http://dx.doi.org/10.1016/j.landurbplan.2013.01.002

2. Conceptual independence of LEED credits

On the one hand, there is the question of correlation among the six categories of LEED credits. We argue that conceptually, the LEED credits are independent from each other, not correlated as Pushkar suggests with the example of Construction Waste Management (MRc2.1, or Materials and Resources credit 2.1) referencing Brownfield Redevelopment (SSc3, or Sustainable Sites credit 3). In the LEED New Construction Reference Guide (USGBC, 2009), the description of each credit includes a section entitled "Related Credits," and of the 56 credits in the 2009 version, 28 reference credits in other categories in the manner to which Pushkar refers. Of the 11 spatially specific credits we chose for further analysis, five mention related credits in the reference guide. Still, even if only half of the credits have a possible correlation, we should consider the nature of that connection in more detail.

When we look more closely at the nature of the relationship between credits, we find that they are *not* related in the sense of one depending on another. For one, the relations are not bi-directional: MRc2.1 references SSc3, but SSc3 does not reference MRc2.1. This is because of the nature of the relation: the entry in the reference guide on Construction Waste Management notes that "If an existing building is found to contain contaminated substances, such as lead or asbestos, these materials should be remediated as required by EPA; see the following credit: SS Credit 3: Brownfield Redevelopment" (USGBC, 2009, p. 358). If a design team is seeking a credit for Construction Waste Management but comes across hazardous materials in the process, the reference guide is suggesting that the team also consider seeking the credit for Brownfield Redevelopment. If, on the other hand, the team is already seeking the credit for Brownfield Redevelopment, it does not follow that they would also seek the credit for Construction Waste Management, since hazardous materials *must* be disposed of according to EPA requirements and cannot be recycled or reused. A might imply B, but B does not imply A.

In other words, the reason that some credits are designated in the reference guide as being related to one another is to encourage the design team to consider how a decision made in one building system will affect other systems. This does not mean that if a team seeks credit X, they will also seek credit Y, or that if they achieve credit A, they cannot also achieve credit B. For example, SSc7.1 on reducing the heat island effect on non-roof elements mentions that if vegetation is chosen as the option to provide shade over a hardtop surface like a parking lot, the design team should consider how irrigating that vegetation might affect project water requirements and thus WEc1. Many of the water efficiency credits are related to energy and atmosphere credits because systems that enable greywater usage or drip irrigation might require extra energy to run or extra commissioning to ensure they are functioning correctly. There is no expectation or requirement that one credit is correlated with or dependent on another, only a suggestion to think holistically during the design process.

3. Empirical independence of LEED credits

At the same time, there is the question of empirically observed correlation among the LEED credits. In short, such correlation does not exist. Empirically, there is no evidence that LEED credits are correlated with each other across categories based on our data of completed, LEED-certified buildings. To take Pushkar's example of MRc2.1 and SSc3, the correlation among the buildings that achieved each of these credits is −0.0488. Less than 5% of the time, if a building received the Construction Waste Management credit, it did *not* also receive the Brownfields Redevelopment credit.

Table 1
Correlations among achieved LEED credits for all LEED-certified buildings as of December 2007. Data source: USGBC. Calculations by authors.

	All LEED credits	LEED credits referencing other credits
Median correlation	0.027	0.039
Greatest negative correlation	−0.201	−0.139
Greatest positive correlation	0.245	0.245
Standard deviation	0.063	0.079

To further investigate this question of dependence, we calculated the correlation across all 57 individual LEED credits, based on how many times each credit has been achieved by a specific LEED-certified building. The median correlation was $r = 0.023$ among the 1396 correlations (Table 1). The highest positive correlation was $r = 0.245$ and the highest negative correlation was $r = -0.201$. With a standard deviation of $\sigma = 0.063$, this means that 95% of all pairs of LEED credits are correlated between $r = -0.104$ and $r = 0.148$; conversely, only 5% of the pairs of LEED credits across categories have less than 10% negative correlation or greater than 15% positive correlation. We then took the 28 credits that reference other credits; since some of these references are many-to-one and some do run in both directions, there were only 50 possible correlations in this smaller group. Here, the median was slightly higher at $r = 0.039$, with the same highest positive correlation of $r = 0.245$ and the highest negative correlation at $r = -0.139$. With a standard deviation of $\sigma = 0.079$, this means that of the LEED credits that specifically refer to other credits within the LEED reference guide, only 5% of the pairs of these credits have a greater negative correlation than −12% or a greater positive correlation than 20%.

4. Conclusion

Based on these figures, we feel confident in saying that LEED credits are not, in fact, empirically correlated or dependent across categories. Nor is there conceptual dependence or correlation across categories; credits are designated as being "related" to each other in order because the choices made to achieve one credit *might* make it easier or harder to achieve other credits, depending on the overall choices the design team has made. For example, achieving a water efficiency credit does not mean that an energy and atmosphere credit will automatically be achieved as well. Based on the conceptual and empirical independence of the LEED categories, we feel that our original results, which were based on location quotients and coefficients of variance in addition to the ANOVA analysis, should stand. In other words, spatially-specific LEED credits such as Water Efficiency vary across regions more than non-spatial credits such as indoor environmental quality.

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