LEED CERTIFICATION AND PATIENT WELLBEING IN GREEN HEALTHCARE FACILITIES

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ABSTRACT

Beyond resource efficiencies, green buildings aim to create healthy indoor environments for building occupants. In terms of improving occupant well-being, a unique case emerges for healthcare facilities, whose patients may be at a vulnerable state. In the U.S., the Leadership in Energy and Environmental Design (LEED) rating system has become the most widely recognized certification system for green buildings, including green healthcare facilities and buildings. Hospitals with high total scores in the LEED rating system are green buildings but may not necessarily be the optimal green healthcare environment from a patient's wellbeing perspective. Certified healthcare facilities were analyzed in terms of their credit valuation to assess whether healthcare facilities prioritize specific criteria that influence patient wellbeing and recovery time. Analysis of results indicate hospitals may be valuing the level of certification more than those credits that were deemed relevant for patient wellbeing and rate of recovery, either due to lack of information or due to economic constraints. To consolidate the previous results and to compare the performance of LEED certified green hospitals to the national average, the Hospital Consumer Assessment of Healthcare Providers and Systems (HCAHPS) survey was analyzed for patients' perspectives on the healthcare facility. Results indicate higher satisfaction in green hospitals' overall patient care performance as well as a greater tendency to recommend green hospitals to others compared to the national average. No statistical significance was found for hospital cleanliness and quietness between green hospitals and the national average.

HIGHLIGHTS

- Hospital LEED scores not directly aligned with credits that affect patient wellbeing
- HCAHPS survey results compared green hospitals to the national average
- Overall patient satisfaction 3.6% higher in green hospitals versus non-green hospitals
- Patients self-reported 5.6% more likeliness to recommend green hospitals to others
- No statistical difference observed for hospital cleanliness or quietness

KEYWORDS

LEED Healthcare, green building, green hospital, patient satisfaction, HCAHPS, hospital design

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1. INTRODUCTION

Green buildings have gained public support due to the benefits they provide to the environment, society, as well as economic gains during the construction and operation of the building. Hospitals and healthcare facilities deal with sensitive populations: the sick and the vulnerable. The primary mission of healthcare facilities is to enhance the wellbeing of their patients and the society overall. The indoor environment of such buildings has direct impacts on the wellbeing and recovery progress of patients. Hence, green buildings in the healthcare industry require a special focus. Not surprisingly, the number of green building certified healthcare facilities are on the rise in the U.S. and globally based on the number of projects registered on the U.S. Green Building Council (USGBC) site (USGBC, 2018).

One of the most critical aspects and success factors of a hospital would be its patient safety and recovery rate. The design of the built environment is known to impact patient safety (Hickam et al., 2003; Joseph and Hamilton, 2008; Mallak et al., 2003; Urlich et al., 2004). The built environment and the benefits of positive design is capable of reducing pain, emotional anxiety, and other physiological indicators of stress (Frumkin and Coussens, 2007).

Numerous efforts in the field of green healthcare design using the method of 'Evidence Based Design' (EBD) have been done. A main goal of such projects is to enhance the healthcare quality in hospitals by putting emphasis on the main factors related to patient wellbeing as well as maximizing staff performance for increased effectiveness in delivering care. Meanwhile, EBD implemented in the architecture of the healthcare facility enhances the indoor atmosphere for staff and visitors in addition to patients (Joseph and Hamilton, 2008; Mallak et al., 2003).

The Agency for Healthcare Research and Quality (AHRQ) has investigated the connection between the working environment and patient safety. AHRQ has characterized the working environment in 5 categories, where one of these categories focuses on the impacts of the physical environment on patient perception of the healthcare facility (Hickam e al., 2003). A study by Seifert and Hickman (2005) showed that physical environmental factors such as design, light, color, temperature and humidity, air quality, and aesthetic aspects of design have improved patient safety and healing rates while also improving staff satisfaction.

Similarly, indoor environmental quality has been considered as an important factor not only for patient recovery, but also for the satisfaction of nurses and other healthcare staff. Studies on the impact of green buildings on their occupants indicate that IEQ impacts occupant comfort to a great extent (Albatici et al., 2015; Golbazi and Aktas, 2016; Altomonte et al., 2019; Carlucci et al., 2014). Among factors that affect IEQ, thermal conditions play an important part in determining occupants comfort levels, and there are state of the art techniques to control thermal conditions while also aiming to reduce their energy consumption (Golbazi and Aktas, 2018; Kim et al., 2018). Availability of daylight and uninterrupted views of nature in hospitals were found to decrease stress levels in the workplace for nurses (Guenther and Hall, 2007). Researchers have also emphasized the impacts of hospital design and configuration of units and nurse stations on nurses' effectiveness towards teamwork, which contributes to patient satisfaction and wellbeing (Gharaveis et al., 2018). There are other studies that have investigated the influence of communal spaces on social interactions between patients, staff, and families (Choi and Bosch, 2013). Shannon et al. (2018) investigated the influence of the redesigned hospital ward on patients' physical and social activity before and after a redesign in a hospital and concluded that increased social and physical activities among patients mostly happened in patient rooms contrary to designed communal places where it was expected. The

study emphasizes the importance of a patient's room environment on patient activities and wellbeing (Shannon et al., 2018).

In one of the fundamental studies on the subject, Ulrich (1984) compared the wellbeing and recovery rates of patients recovering after a surgery staying in hospital rooms with windows facing trees and another group of patients staying in rooms with windows facing brick walls, and showed that the former group of patients had experienced shorter recovery time compared to the latter group. Accordingly, it was concluded that the built environment had a significant impact on patient recovery and wellbeing. Another study by Joarder and Price (2013) has been done on 263 patients to evaluate the importance of indoor environmental quality focusing on daylight and provision of view. The study indicates that length of stay decreases 7.3 hours by increasing light intensity by 100 lux inside the in-patient rooms. Length of stay also decreases by 17.4 hours using provision of view. The study also found that daylight had greater impact than other variables (Joarder and Price, 2013). Another study by Phiri and Chen (2014) focusing on Evidence-Based Design presented the impact of environmental variables and argued the importance of daylight on patient recovery and its effects on the physiology and psychology of patients. Orians and Heerwagen (1992) also mentions availability of sunlight in patient rooms as an important factor associated patient wellbeing and a reduction in medical costs. Similarly, a study by Beauchemin and Hays (1998) indicates a positive impact of bright, sunny rooms on patients experiencing heart attacks. Researchers found evidence that lighter and brighter rooms in hospitals reduces the stress and pain levels, and results in shorter hospital stays for patients with depression or bipolar disorder (Beauchemin and Hays, 1998; Benedetti et al., 2001; Walch et al., 2005).

Patients need a healthy environment in order to be healthy in a psychological sense. Therefore, healthcare facilities need to provide a pleasing environment similar to that found in the natural environment by connection to the natural world (Frumkin and Coussens, 2007). Hospital quietness can also play an important role in patient satisfaction and their healing process since hospitals are noise-sensitive environments, and there are indications that hospital noise levels have on average increased in past decades (Berglund et al., 1995). A review by Basner et al. (2014) indicate that unpleasant noises worsen patient health outcomes, such as increased cardiovascular stress, longer healing times, increased patient readmission rates, more frequent headaches, and increased sensitivity to pain (Basner et al., 2014; Biley, 1994). Such environments also increase the stress level among hospital staff (Blumkvist et al., 2015). Disturbing noises can be intensified by hard surfaces, and unpleasant noises can cause sleeping disorders for patients that affect health recovery (Topf, 1992). Iyendo (2016) has studied the impacts of playing music in healthcare environments and concluded that playing soothing music not only does not have negative impacts on patient wellbeing, but also helps to reduce stress, blood pressure and post-operative trauma when compared to silence. A study by Shertzer and Keck (2001) showed patients experienced less pain when noise was reduced and replaced with music.

In one of the important studies on the subject, Bilec et al. (2010) studied building design and performance and compared a newly renovated Leadership in Energy and Environmental Design (LEED) certified green healthcare facility, which incorporated features such as improved daylight, a green roof, healing gardens, private patient rooms, compared to its previous traditional structure. The impacts of the built environment on hospital's performance and on patients and staff was studied. The study concluded that following the move into the new LEED-certified building, the hospital reported improved productivity, quality of care, and staff satisfaction, and

reduced utility use per square meter, while their expense per patient remained constant during this time (Bilec et al., 2010; Thiel et al., 2014). In another study by Campion et al. (2016), the Hospital Consumer Assessments of Healthcare Providers and Systems (HCAHPS) survey was utilized to understand changes in patient satisfaction for the same unit hospital before and after renovation for a 3-year period. The study has evaluated 16 HCAHPS questions and found significant improvements in patient satisfaction in 7 out of 16 questions (Campion et al., 2016).

Beyond their environmental, societal, and direct economic benefits, green buildings also appeal to institutions due to their other indirect benefits such as improved public image, environmental stewardship, or in some cases simply as a marketing tool. Therefore, hospitals may become certified green building, but that may not necessarily indicate an ideal healthcare environment from a patient wellbeing point of view. The goal of the study was to identify whether healthcare facilities actually value the specific criteria that influence patients' health and their recovery period. The LEED green building rating system and the data provided by USGBC, which administers the LEED rating system have been used. A statistical correlation among total points received by certified healthcare facilities and number of patient wellbeing points was also carried out.

1.1 LEED: Leadership in Energy and Environmental Design

The LEED certification program is a rating system developed for green buildings. It aims to incentivize a healthier, more responsible, and more sustainable way for buildings to be designed, constructed, maintained, and operated. The main aims of the rating system can be classified into 6 categories (USGBC, 2018):

- Location and transportation
- Sustainable site planning
- Water efficiency
- Energy and atmosphere
- Materials and resources
- Indoor environmental quality

To receive LEED certification, buildings should meet all prerequisites and obtain points above a threshold to be certified. Prerequisites are mandatory and do not encompass any points for the certification process (USGBC, 2009). There are four levels of building certification in the LEED rating system: Certified; Silver; Gold; and Platinum. The number of points each project receives determines the level of LEED certification. The LEED rating system together with its checklist, types of credits, and total potential points has undergone multiple revisions over the years. Table 1 summarizes total points allowed towards certification and the levels of certification in LEED v3 2009 and LEED v2.2, which are used in this study. The study does not include LEED v4 as there were not enough hospitals yet certified under that version.

1.2 LEED for Healthcare

LEED for Healthcare is provided for inpatient and outpatient healthcare facilities and licensed long-term care facilities. The rating system is specific for healthcare environments and encompasses particular strategies relevant to healthcare environments. Bases of standards are similar to other rating systems under LEED and are similarly classified in categories. However, there are specific credits under each category that are relevant for sensitive healthcare environments

TABLE 1. Total Point and Certification Level Summaries for LEED v3 2009 and LEED v2.2 New Construction (USGBC, 2005; USGBC, 2009).

	LEED v3 2009 Points	LEED v2.2 Points
Base	100	64
Innovation in design	6	5
Regional priority	4	—
Total	110	69
Certified	40–49	26–32
Silver	50–59	33–38
Gold	60–79	39–51
Platinum	80+	52+

(USGBC, 2012). Healthcare facilities have strict and intensive criteria due to the sensitivity of operations and vulnerability of occupants. Healthcare facilities are distinctly different from other types of buildings and use and require day-round operations, have intensive energy and water use (CBECS, 2012), have specific infection control requirements (Sehultzer et al., 2003), and a heightened need for patient privacy.

1.3 LEED for New Construction

While LEED New Construction was designed for new buildings, many other building types were initially certified under this category. Commercial buildings as defined by standard building codes are eligible for certification under LEED for New Construction such as offices, institutional buildings (libraries, museums, churches, etc.), hotels, and residential buildings of 4 or more habitable stories (USGBC, 2009). The diverse list of facilities and uses included hospitals as well. Among the certified hospitals listed through USGBC, 81 of them were found to be scored under the "New Construction" version 2.2 and version 3 (USGBC, 2018). As this number formed a significant portion of certified green healthcare buildings, New Construction credits in version 2.2 and version 3 that were relevant or similar to patient wellbeing credits were reviewed in this study.

1.4 HCAHPS: Hospital Consumer Assessments of Healthcare Providers and Systems

Hospital Consumer Assessments of Healthcare Providers and Systems (HCAHPS), which is also known as the CAHPS hospital survey, provides a standardized survey instrument for data collection and uses a rating scale to assess patient perspectives and satisfaction on care they received during their stay in healthcare facilities (Goldstein, 2005; Medicare, 2018). HCAHPS was nationally implemented for hospitals beginning October 2006 by agreement between AHRQ and the Centers for Medicare & Medicaid Services (Goldstein, 2005). Its implementation started by participation on a volunteer basis. HCAHPS hospital survey was supported by the Hospital Quality Alliance and quickly gained support from numerous institutions (Giordano et

al., 2010). Research show that consumer reports have resulted in improvements in the quality of hospital care provided to patients (Giordano et al., 2010).

Building on the study by Golbazi and Aktas (2016), the current study has further analyzed the results of four questions which are most closely associated with the hospitals' physical aspects: hospital quietness; hospital cleanliness; hospital's overall score rated by the patient; and whether the patient would recommend the hospital to others in the future.

2. METHODS

Data on certified healthcare facilities for this study were primarily obtained from the USGBC website. LEED scorecards for certified hospitals have been reviewed to assess which credits hospitals and healthcare facilities received during certification. There is a total of 140 LEED certified hospitals whose scorecards have been analyzed for specific selected criteria in this study. Among those, 59 hospitals were certified under the "Healthcare" category, and 81 hospitals were certified under the "New Construction" category.

A scorecard is attributed to each certified hospital or healthcare facility. As the scorecard of every hospital is publicly available, the total scores received were analyzed. In line with the goal of the study however, the most relevant credits to patient wellbeing have been further analyzed. As a result, hospitals have been evaluated in two steps. First, as a green building according to their total score which has been provided by USGBC, and second as a healthy healthcare environment which has been developed by this study according to their performance in patient wellbeing credits.

To study 59 hospitals under the LEED Healthcare category, credits under the healthcare scorecard that were relevant to the wellbeing of patients were selected to evaluate the hospital's efforts specifically towards healthcare credits. However, as most of the green hospitals were certified under the New Construction category in previous years and versions of LEED rather than under LEED Healthcare, it was deemed necessary to identify credits relevant to patient wellbeing in other, previous scorecards as well. LEED credits chosen for the analysis from each of the respective rating systems are presented in Table 2.

The selection of respective credits was conducted by identifying important factors for patient wellbeing and recovery from academic literature. Credits selected from "Sustainable sites," "Indoor Environment Quality (IEQ)" and "Materials and Resources" given in Table 2 were identified in the literature as being most relevant to patient wellbeing.

The scorecards for the 140 hospitals have been evaluated, and their total score as well as their patient wellbeing score based on the developed model have been calculated and compared to each other. This data has been statistically analyzed to seek correlations among the two variables.

2.1 Statistical Analysis

Since studied hospitals were certified under different versions of LEED, they differed for total and healthcare scores that could be achieved. Rather than evaluate these scores as points, it was necessary to modify scores to a percentage in this study. Using percentages enabled comparison between scores, and as a result, to analyze the differences. Basic descriptive statistical measures of each dataset were calculated. The mean of the data was used to compare to other categories and were reported in the study. A correlation analysis between total points and healthcare points received was carried out to seek underlying trends in data.

TABLE 2. Patient wellbeing credits analyzed in the study under various LEED rating system.

	LEED Healthcare (potential points)	LEED New Construction v2.2 (potential points)	LEED New Construction v3 (potential points)
Sustainable Sites	Site development—maximize open space (1)	Site development—maximize open space (1)	Site development—maximize open space (1)
	Light pollution reduction (1)	Light pollution reduction (1)	Light pollution reduction (1)
	Connection to the natural world—places of respite (1)		
	Connection to the natural world—direct exterior access for patients (1)		
Materials and Resources	PBT source reduction—mercury in lamps (1)		
	PBT source reduction—lead, cadmium and copper (2)		
	Furniture and medical furnishings (2)		
Indoor Environment Quality (all)	All	All	All

Results of the analysis comparing HCAHPS results for green hospitals and the national average were tested for significance using a t-test hypothesis test for two samples at the 5% significance level. Conclusions derived from that analysis are based on the results of the hypothesis test.

2.2 HCAHPS: Hospital Consumer Assessments of Healthcare Providers and Systems

To consolidate previous results and to understand the difference between LEED certified green hospitals and hospitals nationwide, HCAHPS survey results were analyzed. HCAHPS provides a standardized survey instrument for data collection and uses a rating scale to assess patient perspectives and satisfaction on care they received (Medicare, 2018). 52 mutual hospitals between HCAHPS and the LEED rating system were studied in terms of their performance. These 52 hospitals were selected based on their data availability from both USGBG and HCAHPS. The aim of utilizing HCAHPS results on top of the LEED rating system was to obtain additional information about LEED certified green hospitals in terms of patient wellbeing factors that are defined by previous studies.

The LEED rating system, with its checklist, mostly considers building design factors, whereas the HCAHPS survey quantifies the patients' experience and their perception of the designed environment, their experience, and the care they received. Therefore, the combination

of data attained from the LEED rating system and data obtained from the survey was believed to provide unique insights that could help both decision makers and policymakers in the healthcare industry as well guide designers of healthcare facilities to consider some additional factors in the criteria designation.

The current study has focused on the results of four questions in the HCAHPS survey that contributed to the hospitals' physical aspects. Hospital quietness, hospital cleanliness, hospitals overall score rated by patients, and whether patients would recommend the hospital to others in the future. Average national HCAHPS scores were obtained for all the hospitals in the country and were compared to the average HCAHPS results available for LEED certified green hospitals.

The survey format provides three options for patients for factors on cleanliness and quietness. Patients can either choose to say the hospital was "always clean/quiet," "usually clean/quiet" or "Sometimes or Never clean/quiet." For the overall score however, patients are required to assign a value within a scale of 0–10. Supported by literature, there are three different categories based on their overall score, and has separated the hospitals into three groups: hospitals that scored 0–6 designated as the poor category; hospitals that scored 7–8 as the average category; and hospitals that scored 9–10 were considered as the top category (Giordano et al., 2010). This study has looked at the top category scores, similar to what HCAHPS dataset utilizes to obtain average national scores (Medicare, 2018). Patients were also asked whether they would "Definitely" or "Probably" recommend the hospital, or they would not recommend it at all. The current study has not considered sections of the survey related to the medical aspects of patient satisfaction, but remained focused on sections relevant to the built environment.

3. RESULTS AND DISCUSSION

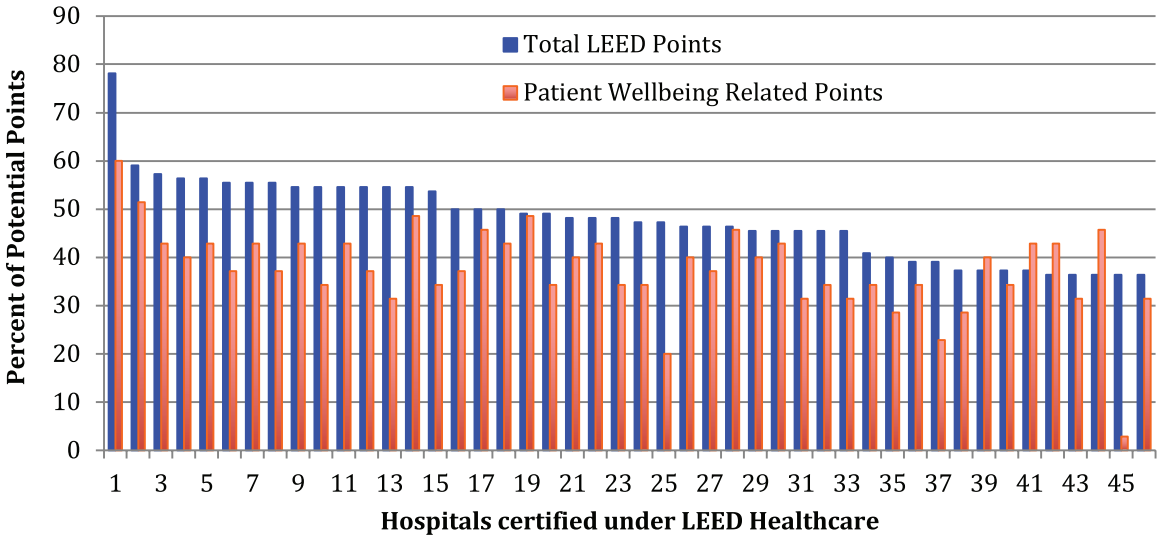
The results of the study regarding overall LEED and patient wellbeing credits were presented and discussed by following the three versions or datasets in the following sections.

3.1. LEED Healthcare

LEED Healthcare category encompasses 59 certified healthcare facilities. Among these 59 hospitals, 16 had received "Certified" level, 28 hospitals had received "Silver" certification, 14 hospitals had received "Gold" certification, and 1 hospital had received "Platinum" level certification. Credits which were directly related to health of the indoor environment and thus to the wellbeing of patients were analyzed in this study. The maximum healthcare score for green buildings under this category was determined to be 35 points based on the selected credits. Analysis results of these credits and the total points received by these hospitals are presented in Figure 1. The mean of total points and patient wellbeing related points were calculated to be 47% and 37%, respectively. This result can be used to suggest that hospitals certified under this rating system had given more attention and dedication to credits that were related to the green building itself, as compared to credits that were relevant to the wellbeing of patients. This is not to suggest that building or resource related credits are not important for hospital buildings, but there is clearly room for improvement for hospitals certified under the Healthcare rating system to increase their share of credits that most affect patient wellbeing, rate of recovery, and satisfaction.

Among the 59 hospitals certified under the Healthcare category, only 4 hospitals had patient wellbeing point percentage higher than overall point percentage, and all 4 had a certification level of 'Certified'. Statistical correlation was sought between the total score of a

FIGURE 1. Total and healthcare scores for hospitals certified based on the LEED v3 Healthcare scorecard.



hospital and patient wellbeing related healthcare specific points. The correlation coefficient was calculated to be 0.53 for the dataset of LEED Healthcare buildings. However, as negative correlations are unlikely in this analysis, as a building receiving high overall points by scoring low on patient wellbeing points is unlikely, the calculated coefficient was lower than anticipated, signaling a weak to moderate correlation between overall points and patient wellbeing points.

3.2 LEED New Construction

3.2.1 New Construction-Version 2.2

Green buildings certified under New Construction-version 2.2 includes 60 hospitals and healthcare facilities. The level of certification distribution among these hospitals were: 9 hospitals at the "Certified" level; 17 at the "Silver" level; 33 hospitals at the "Gold" certification level; and 1 hospital at the "Platinum" level of certification. Figure 2 presents the total score of buildings analyzed together with patient wellbeing scores as a percentage of potential points. The maximum healthcare score for green buildings under this category was determined to be 17 points based on the selected credits. The maximum overall score a building could receive under the rating system was 69 in this version of LEED. The mean percent of total and patient wellbeing scores were calculated as 72% and 54%, respectively.

Among the 60 hospitals studied under this category, all 60 hospitals were found to have higher percent of patient wellbeing scores compared to their overall total score. From the function and mission of a hospital building perspective, this outcome may be deemed desirable based on the connection between patient wellbeing and the built environment in a hospital setting. For instance, using a minimum of 50% wood-based materials and products as required by credit MRc7 may be an important factor for a green building in terms of its resource sourcing and efficiency. However, it can be argued that it is secondary when compared to indoor chemical and pollutant source control required by credit EQc5, which is critical to have a healthy indoor

environment for inbound patients who are already vulnerable and spend the majority of their stay inside hospital rooms and buildings.

The correlation coefficient for the dataset was calculated to be 0.55, again signaling weak to moderate correlation between the two variables similar to the case in LEED Healthcare. Considering the fact that the two variables of healthcare score and total score were not independent variables, the calculated value was not judged to be high enough to suggest a direct link between the two variables. There is comparable variation in results of dataset LEED v2.2 as compared to dataset of buildings certified under LEED Healthcare, although close inspection of results indicates that overall points are higher than patient wellbeing points in LEED Healthcare, and the opposite is true in LEED v2.2.

3.2.2 New Construction-Version 3

Out of the total of 81 hospitals certified under the New Construction category, 21 were certified based on the LEED version 3 scorecard. As for the distribution of certification levels in v3: 3 hospitals had received "Certified" level; 12 hospitals had received "Silver" level; 5 hospitals had received "Gold" level; and 1 hospital had received "Platinum" level. Figure 3 presents total and patient wellbeing related credits of these hospitals as a percent of their potential total. The maximum healthcare score for green buildings under this category was determined to be 24 points based on the selected credits. According to these results, the mean of patient wellbeing scores among the 21 certified hospitals was 43%, as compared to the mean of total scores at 50%. Among the 21 hospitals studied under this category, only 3 hospitals were found to have higher percent of patient wellbeing scores compared to their overall total score. These results may suggest that hospitals that have been evaluated under LEED New Construction version 3 have also paid less attention to the critical features of the building that affect patient wellbeing.

The correlation coefficient was calculated to be 0.44 for the dataset. However, considering the fact that the two variables of healthcare score and total score were not independent variables,

FIGURE 2. Total LEED and patient wellbeing related points for hospitals and healthcare facilities certified under the LEED New Construction v2.2 scorecard.

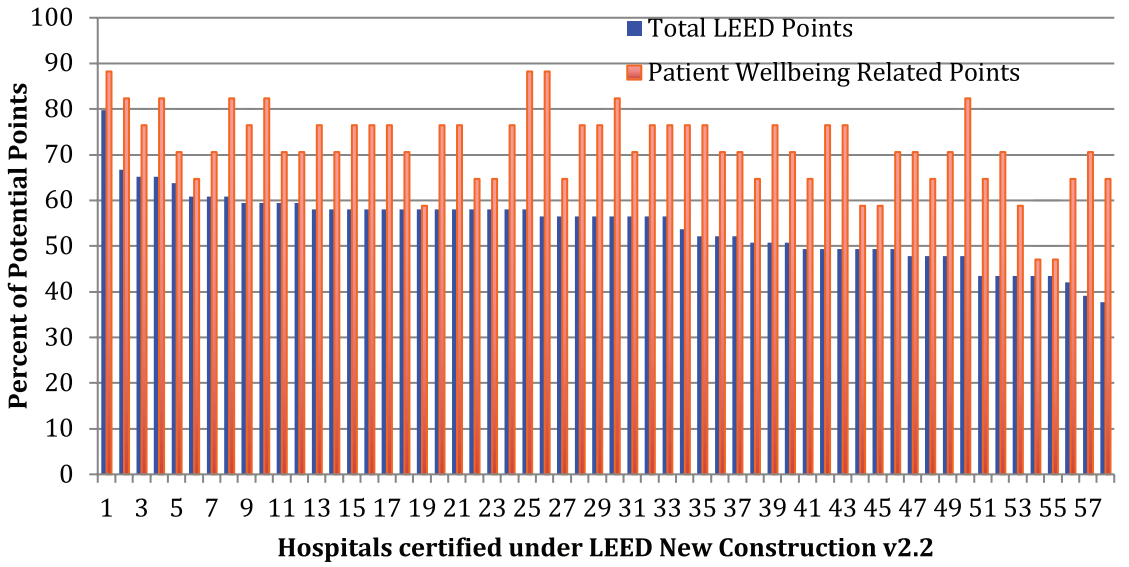
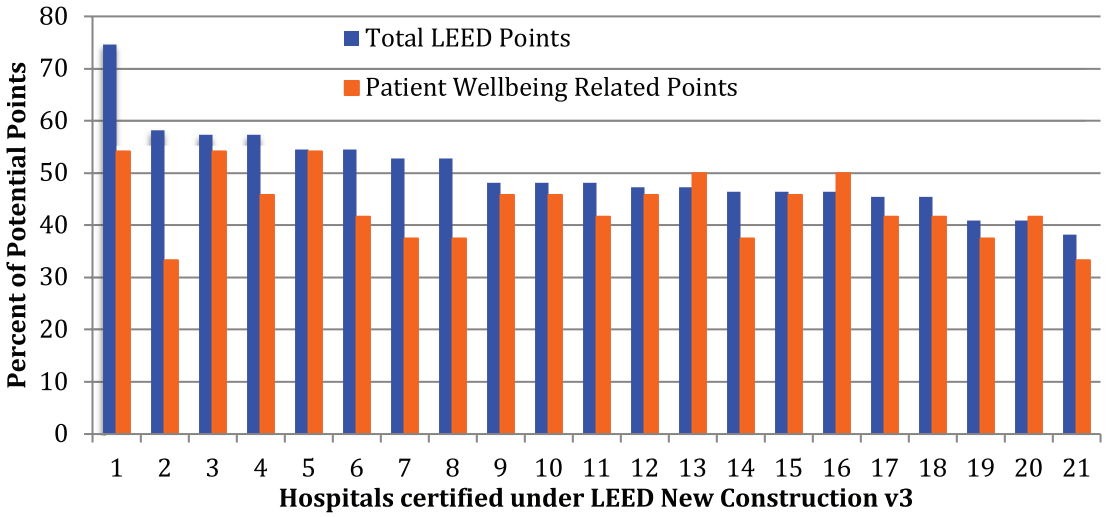


FIGURE 3. Total and healthcare scores for hospitals certified based on the LEED New Construction v3 scorecard.



the calculated value was not judged to be sufficient to suggest a causal link between the two variables. On the contrary, there seem to be only weak support to claim that hospitals that receive high total scores and thus certification levels have higher patient wellbeing points as well.

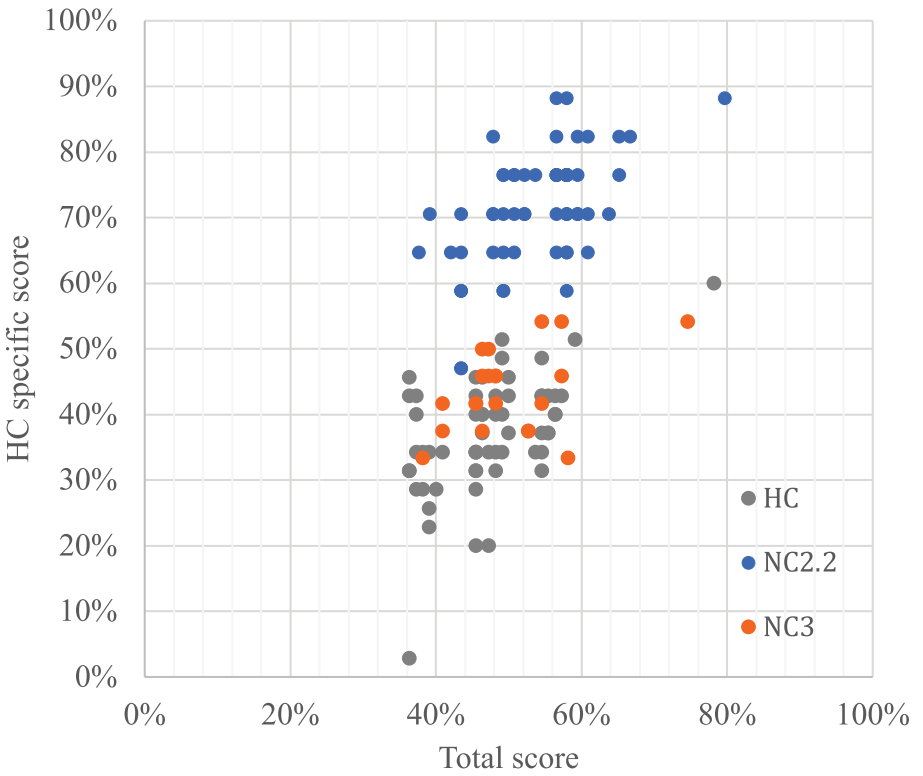
3.3 Evaluation of overall LEED points and patient wellbeing points for green healthcare facilities

Based on the analysis results, the mean of the percent healthcare score was calculated as 43% for hospitals certified under New Construction v3, 72% for hospitals certified under New Construction v2.2, and 37% for those certified under the Healthcare rating system. Based on these results, it was concluded that hospitals certified under New Construction v2.2 have had a stronger attempt at incorporating more elements from the scorecard that affect patient health and wellbeing when compared to hospitals certified under New Construction v3, or even those certified under the Healthcare rating system. While hospitals included in the Healthcare category were initially expected to have the higher percentages for patient wellbeing related credits, they proved to have the lowest percent of relevant points in this analysis. Figure 4 presents the distribution of hospitals certified under various categories with their total and Healthcare specific scores.

As indicated in Figure 4, most healthcare facilities appear to be within a 40%–60% range in terms of total score received independent of the version of LEED. Yet, hospitals certified under NC version 2.2 seem to have somewhat higher total scores than those in the other two versions of LEED. What is more important is that hospitals certified under older version of LEED (New Construction v2.2) have statistically significant higher patient wellbeing specific scores. The healthcare and new construction v3 versions fall into similar ranges, receiving lower scores specific for patient wellbeing.

The results can be attributed to a number of potential factors. This could have been caused by heightened restrictions and requirements of credits in the Healthcare scorecard that directed stakeholders away from patient wellbeing related credits as they were perceived to be more

FIGURE 4. Total and Healthcare specific score distribution of hospitals certified under different LEED categories.



difficult to achieve. The other explanation could be that hospitals may be valuing the level of certification more than those credits that were deemed relevant for patient wellbeing and rate of recovery, either due to lack of information or due to economic constraints. Therefore, results may indicate changing priorities of stakeholders in hospital design and construction over the years between LEED v2.2 and v3 or LEED Healthcare, where the focus may have shifted towards buildings' resource efficiency as compared to providing pleasing environments for patients. The negative trend may also be due to LEED reduced emphasis on factors related to patient wellbeing such as IEQ, in favor of non-relevant factors such as energy and water efficiency.

3.4 HCAHPS Survey Results

To assess patients' perspectives on green healthcare facilities and to compare to non-green hospitals, the HCAHPS database was analyzed. Four most relevant factors for patient wellbeing in terms of hospital environment were studied. Table 3 provides the results of the analysis for LEED certified hospitals compared to the national average. Survey results indicate that green hospitals were generally ranked higher in three of the four factors analyzed for patient satisfaction.

For perceived hospital cleanliness and hospital quietness, cumulative average results did not indicate a difference among green hospitals and the national average based on the HCAPHS survey results. Results indicate that patients rate green hospitals slightly favorable in terms of overall facility rating, with green hospitals being rated 3.6% higher compared to the national average. Average scores for when patients were asked whether they would recommend the facility to others resulted in 5.6% higher scores for green hospitals compared to the national average.

TABLE 3. Comparison of the HCAHPS hospital survey results analysis on select parameters separated for LEED certified green hospitals and the national average, given in percent.

	Cleanliness, (%)	Quietness, (%)	Overall Rating, (%)	Recommendation, (%)
LEED—New Construction v2.2	76.0	64.3	76.5	77.1
LEED—New Construction v3	72.4	59.8	77.8	80.6
LEED—Healthcare	74.9	64.6	75.8	76.7
LEED Certified Green Hospitals, Weighted Average	75.2	63.6	76.6	77.6
National Average	75	62	73	72

However, caution is advised related to the latter two points as other factors related to patients' overall attitudes about the hospital, such as medical care they received, quality and attitude of staff and personnel may have affected their overall hospital perception and whether to recommend the facility to others.

Following the conducted hypothesis test for two samples using a t-test, it was concluded that there is a statistical difference in the results for the overall hospital rating and whether patients would recommend the hospitals to others at the 5% significance level. Statistical significance was not observed for hospital cleanliness and quietness based on the survey results.

4. CONCLUSION

Design of hospitals have been shown to impact patient wellbeing and recovery periods for inbound patients. The study analyzed LEED certified green healthcare facilities to assess to what extend hospitals and healthcare facilities value the specific credits and criteria that influence patients' health and wellbeing.

According to statistical analysis, the mean of the percent patient wellbeing score was calculated as 37% for those certified under Healthcare, 43% for hospitals certified under New Construction v3, and 72% for hospitals certified under New Construction v2.2 rating systems. Based on these results, it was concluded that hospitals certified under New Construction v2.2 have had a stronger attempt at incorporating more elements from the scorecard that affect patient health and wellbeing when compared to hospitals certified under New Construction v3, or even those certified under the Healthcare category. While hospitals included in the Healthcare category were initially expected to be the most successful ones in terms of achieving patient recovery and wellbeing related credits, they proved to earn the lowest percent of relevant points in this analysis. Correlation coefficients calculated for the three datasets were not sufficiently strong. At best, they were found to weakly or moderately support the claim that overall total scores and patient wellbeing scores were correlated.

Results indicate that change from one version of LEED to its next iteration has decreased the incorporation of patient wellbeing related features in healthcare buildings. This result does

not bode well from a patient wellbeing point of view, and future versions of LEED should consider steps at emphasizing studied credits especially in healthcare design.

Based on the analyzed HCAHPS survey results, cumulative average results did not indicate a difference among green and non-green hospitals for perceived hospital cleanliness and quietness. Results indicate that patients rate green hospitals slightly favorable in terms of overall facility rating, with green hospitals being rated 3.6% better compared to the national average. Similarly, average scores for when patients were asked whether they would recommend the facility to others were 5.6% higher for green hospitals compared to the national average. However, caution is advised related to the latter two points as other factors related to patients' overall attitudes about the hospital, such as the quality of medical care they received, attitude of staff and medical personnel may have affected their overall hospital perception and whether to recommend the facility to others.

In conclusion, hospitals seeking LEED certification should more strongly pursue credits identified in the study that affect patient wellbeing as there is sufficient literature to warrant the influence of the built environment on patients as well as hospital staff. Only seeking higher LEED scores is not sufficient as was shown in the study, as hospitals with high total scores may be green buildings but not necessarily the optimal green healthcare environment due to the mix of credits they received.

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REFERENCES

1. Albatici, R., Genetti, F., & Marinelli, M. (2015). Summer Comfort in Exposed Concrete Free Running Buildings. Energy Procedia, 78, 2935–2940, https://doi.org/10.1016/j.egypro.2015.11.671
2. Altomonte, S., Schiavon, S., Kent, M. G., & Brager, G. (2019). Indoor environmental quality and occupant satisfaction in green-certified buildings. Building Research & Information, 47(3), 255–274, https://doi.org/10.1080/09613218.2018.1383715
3. Basner, M., Babisch, W., Davis, A., Brink, M., Clark, C., Janssen, S., Stansfeld, S., 2014. Auditory and non-auditory effects of noise on health. The Lancet. 383, no. 9925, 1325–1332. https://doi.org/10.1016/S0140-6736(13)61613-X
4. Beauchemin, K.M., Hays, P., 1998. Dying in the dark: sunshine, gender and outcomes in myocardial infarction. Journal of the Royal Society of Medicine. 91, no. 7, 352–354. https://doi.org/10.1177/014107689809100703
5. Benedetti, F., Colombo, C., Barbini, B., Campori, E., Smeraldi, E., 2001. Morning sunlight reduces length of hospitalization in bipolar depression. Journal of Affective Disorders. 62, no. 3, 221–223. https://doi.org/10.1016/S0165-0327(00)00149-X
6. Berglund, B., Lindvall, T., Schwela, D.H., 1999. Guidelines for community noise. World Health Organization—Occupational and Environmental Health Team. Geneva, World Health Organization. http://www.who.int/iris/handle/10665/66217
7. Bilec, M.M., Geary, M., Ries, R.J., Needy, K.L., Cashion., M.K., 2010. A method for quantifying the benefits of greening a healthcare facility. Engineering Management Journal. 22, no. 3, 3–11. https://doi.org/10.1080/10429247.2010.11431867
8. Biley, F.C., 1994. Effects of noise in hospitals. British journal of nursing. 3, no. 3, 110–113. https://doi.org/10.12968/bjon.1994.3.3.110
9. Blomkvist, V., Eriksen, C.A., Theorell, T., Ulrich, R., Rasmanis, G., 2005. Acoustics and psychosocial environment in intensive coronary care. Occupational and environmental medicine. 62, no. 3. https://doi.org/10.1136/oem.2004.017632

10. Campion, N., Thiel, C.L., Focareta, J., Bilec, M.M., 2016. Understanding green building design and healthcare outcomes: Evidence-based design analysis of an oncology unit. Journal of Architectural Engineering. 22, no. 3. https://doi.org/10.1061/(ASCE)AE.1943-5568.0000217
11. Carlucci, S., Pagliano, L., O'Brien, W., & Kapsis, K. (2015). Comfort considerations in Net ZEBs: theory and design. Modeling, Design, and Optimization of Net-Zero Energy Buildings, 75–106 (eds A. Athienitis and W. O'Brien), Wilhelm Ernst & Sohn, Berlin, Germany. http://dx.doi.org/10.1002/9783433604625.ch03
12. CBECS, 2010. Commercial Buildings Energy Consumption Survey (CBECS)—Energy Characteristics and Energy Consumed in Large Hospital Buildings in the United States in 2007. https://www.eia.gov/consumption/commercial/reports/2007/large-hospital.php (accessed 17 August 2012).
13. Choi, Y.S., Bosch, S.J., 2013. Environmental Affordances: Designing for Family Presence and Involvement in Patient Care. HERD: Health Environments Research & Design Journal.6, 4, 53–75. https://doi.org/10.1177/193758671300600404
14. Frumkin, H., Coussens, C., 2007. Green Healthcare Institutions: Health, Environment, and Economics: Workshop Summary. National Academies Press, Washington, D.C.
15. Gharaveis, A.D. Hamilton, K., Pati, D., 2018. The impact of environmental design on teamwork and communication in healthcare facilities: A systematic literature review. HERD: Health Environments Research & Design Journal. 11, 1, 119–137. https://doi.org/10.1177/1937586717730333
16. Giordano, L.A., Elliott, M.N., Goldstein, E., Lehrman, W.G., Spencer., P.A., 2010. Development, implementation, and public reporting of the HCAHPS survey. Medical Care Research and Review 67, no. 1, 27–37. https://doi.org/10.1177/1077558709341065
17. Golbazi, M., Aktas, C.B., 2018. Energy efficiency of residential buildings in the US: Improvement potential beyond IECC. Building and Environment, 142, 278–287, https://doi.org/10.1016/j.buildenv.2018.06.029
18. Golbazi, M., Aktas, C.B., 2016. Analysis of Credits Earned by LEED Healthcare Certified Facilities. Procedia Engineering, 145, 203–210, https://doi.org/10.1016/j.proeng.2016.04.062
19. Goldstein, E., Farquhar, M., Crofton, C., Darby, C., Garfinkel, S., 2005. Measuring hospital care from the patients' perspective: An overview of the CAHPS hospital survey development process. Health Services Research 40, no. 6 p2, 1977–1995. https://onlinelibrary.wiley.com/doi/abs/10.1111/j.1475-6773.2005.00477.x
20. Guenther, R., Hall, A.G., 2007. Healthy buildings: impact on nurses and nursing practice. OJIN: The Online Journal of Issues in Nursing. 12, 2. https://doi.org/10.3912/OJIN.Vol12No02Man02
21. Hickam, D.H., Severance, S., Feldstein, A., Ray, L., Gorman, P., Schuldheis, S., Hersh, W.R., Krages, K.P., Helfand, M., 2003. The effect of health care working conditions on patient safety. AHRQ Evidence Report Summaries, 74.
22. Iyendo, T.O., 2016. Exploring the effect of sound and music on health in hospital settings: A narrative review. International journal of nursing studies. 63, 82–100. https://doi.org/10.1016/j.ijnurstu.2016.08.008
23. Joarder, A.R., Price, A.D.F., 2013. Impact of daylight illumination on reducing patient length of stay in hospital after coronary artery bypass graft surgery. Lighting Research & Technology. 45, no. 4, 435–449. https://doi.org/10.1177/1477153512455940
24. Joseph, A., Hamilton, D.K., 2008. The Pebble Projects: coordinated evidence-based case studies. Building Research & Information. 36, no. 2, 129–145. https://doi.org/10.1080/09613210701652344
25. Kim, J., Schiavon, S., Brager, G., 2018. Personal comfort models–A new paradigm in thermal comfort for occupant-centric environmental control. Building and Environment, 132, 114–124, https://doi.org/10.1016/j.buildenv.2018.01.023.
26. Mallak, L.A., Lyth, D.M., Olson, S.D., Ulshafer, S.M., Sardone, F.J., 2003. Culture, the built environment and healthcare organizational performance. Managing Service Quality: An International Journal. 13, no. 1, 27–38. https://doi.org/10.1108/09604520310456690
27. Medicare, 2018. Hospital Compare. Centers for Medicare & Medicaid Services, Baltimore, MD. https://www.medicare.gov/hospitalcompare/About/What-Is-HOS.html (accessed June 2018).
28. Orians, G.H., Heerwagen, J.H., 1992. Evolved responses to landscapes. In J. H. Barkow, L. Cosmides, J. Tooby (Eds.), The adapted mind: Evolutionary psychology and the generation of culture (pp. 555–579). New York, NY, US: Oxford University Press.
29. Phiri, M., Chen, B., 2014. Sustainability and evidence-based design in the healthcare estate. Springer. https://doi.org/10.1007/978-3-642-39203-0

30. Sehulster, L., Chinn, RYW., Arduino, M.J., Carpenter, J., Donlan, R., Ashford, D. et al. 2003. Guidelines for environmental infection control in health-care facilities. U.S. Department of Health and Human Services Centers for Disease Control and Prevention (CDC). https://www.cdc.gov/infectioncontrol/pdf/guidelines/environmental-guidelines.pdf
31. Seifert, P., Hickman, D., 2005. Enhancing patient safety in a healing environment. Topics in Advanced Practice Nursing eJournal. 5, 1, 97–114.
32. Shannon, M.M., Elf, M., Churilov, L., Olver, J., Pert, A., Bernhardt, J., 2018. Can the physical environment itself influence neurological patient activity?. Disability and Rehabilitation. 1–13. https://doi.org/10.1080/09638288.2017.1423520
33. Shertzer, K.E., Keck, J.F., 2001. Music and the PACU environment. Journal of Perianesthesia Nursing. 16, no. 2, 90–102. https://doi.org/10.1053/jpan.2001.22594
34. Thiel, C.L., Needy, K.L., Ries, R., Hupp, D., Bilec, M.M., 2014. Building design and performance: A comparative longitudinal assessment of a Children's hospital. Building and Environment. 78, 130–136. https://doi.org/10.1016/j.buildenv.2014.04.001
35. Topf, M., 1992. Stress effects of personal control over hospital noise. Behavioral Medicine. 18, no. 2, 84–94. https://doi.org/10.1080/08964289.1992.9935176
36. Ulrich, R.S., 1984. View through a window may influence recovery from surgery. Science. 224, no. 4647, 420–421. https://doi.org/10.1126/science.6143402
37. Urlich, R., Zimring, C., Quan, X., Joseph, A., Choudhary, R., 2004. The role of the physical environment in the hospital of the 21st century. The Center for Health Design.
38. USGBC, 2005. LEED for new construction & major renovations, Version2.2, United States Green Building Council.
39. USGBC, 2009. LEED 2009 for New Constructions and Major Renovations Rating System, United States Green Building Council.
40. USGBC, 2012. LEED 2009 for Healthcare, United States Green Building Council.
41. USGBC, 2018. United States Green Building Council. http://www.usgbc.org/leed; (accessed June 2018).
42. Walch, J.M., Rabin, B.S., Day, R., Williams, J.N., Choi, K., Kang, J.D., 2005. The effect of sunlight on postoperative analgesic medication use: a prospective study of patients undergoing spinal surgery. Psychosomatic Medicine. 67, no. 1, 156–163. https://doi.org/10.1097/01.psy.0000149258.42508.70