ABSTRACT

As the need for environmental certification systems grows, Leadership in Energy and Environmental Design for New Construction (LEED-NC) is being widely adopted in the US to evaluate the environmental performance of buildings. However, no research has been conducted to investigate its economic impact on appraised land value. The objectives of this study are to quantify the impact of the LEED-NC Credit Alternative Transportation: Public Transportation Access (PTA) in the sustainable sites category on appraised land value and to develop a regression model that predicts the appraised unit value of parcels. San Francisco County was chosen because of its well-organized transportation systems. First, a LEED-NC map was created to identify PTA-qualified parcels. Second, sample parcels were randomly selected. Last, Pearson’s correlation analysis, one-way ANOVA, and multiple linear regression analysis were sequentially performed. The results of this study indicated that the LEED PTA criteria are significant factors associated with an increase in the appraised unit value of parcels within San Francisco County. The findings of this study can encourage real-estate developers to site their projects according to the LEED-NC PTA criteria.

KEYWORDS
sustainable development, geographic information systems, public transportation

GROWING NEED FOR AN ENVIRONMENTAL CERTIFICATION SYSTEM

The construction industry is considered one of the major contributors to environmental pollution. The International Energy Agency (IEA) reported that existing buildings are responsible for more than 40% of the world’s total primary energy consumption and for 24% of global carbon dioxide emissions (USGBC 2009). In addition, the residential and commercial construction sectors alone comprise approximately 38% of the total Canadian secondary energy
use and generate 30% of the total Canadian greenhouse gas emissions (Schedler and Udall 2005). Furthermore, commercial buildings consume the greatest quantity of resources in the US, including 72% of electricity consumption, 39% of energy use, 38% of all carbon dioxide (CO$_2$) emissions, 40% of raw materials use, 30% of waste output (136 million tons annually), and 14% of potable water consumption (USGBC 2009). These statistics indicate the necessity for environmental certification systems to encourage sustainable building development. Therefore, in order to encourage sustainable development in recent years, environmental certification systems such as Green Star (Australia), Leadership in Energy and Environmental Design (LEED) (US), Energy Star (US), and Green Globes (US) have been developed.

**LEED GREEN BUILDING RATING SYSTEM**

Leadership in Energy and Environmental Design (LEED) is considered one of the most favored sustainability rating systems in the US (Gonchar 2005). LEED has evolved since its original inception in 1998 to more accurately represent and incorporate emerging green building technologies (USGBC 2009). The first LEED version 1.0 was launched in 1998 and version 3.0 was released in 2009. Today, LEED consists of the following nine rating systems: 1) LEED for New Construction and Major Renovations (LEED-NC), 2) LEED for Core & Shell, 3) LEED for Schools, 4) LEED for Retail, 5) LEED for Healthcare, 6) LEED for Commercial Interiors, 7) LEED for Existing Buildings, 8) LEED for Neighborhood Development, and 9) LEED for Homes (LEED 2009). Among them, LEED-NC is the most widely adopted rating system. Since its launch in 2000, approximately 54% of all LEED certified projects in the US have been certified by LEED-NC (USGBC 2010). LEED-NC is designed to guide and distinguish high-performance commercial and institutional projects such as the construction of office buildings, high-rise residential buildings, government buildings, recreational facilities, manufacturing plants, and laboratories. LEED-NC is now being utilized in many countries including China, Korea, India, and Canada (USGBC 2007).

**LEED-NC SUSTAINABLE SITE CREDITS**

LEED-NC defines the leadership position for designing and building commercial, institutional, government, and high-rise residential buildings of all sizes in a way that produces quantifiable benefits for occupants, the environment, and their owners (USGBC 2009). It has emerged as the national leader in market transformation of the commercial sector, making a convincing value proposition for building green (USGBC 2011). Since its launch in 2000, over 4,000 building projects have been certified for LEED-NC in the US (USGBC 2011). The primary goal of LEED-NC is to promote healthful, durable, affordable, and environmentally sound practices in building design and construction (USGBC 2009). LEED-NC levels are awarded according to the following:

- **Certified**: 40–49 credits
- **Silver**: 50–59 credits
- **Gold**: 60–79 credits
- **Platinum**: 80 points and above

LEED-NC addresses seven categories, sustainable sites, water efficiency, energy and atmosphere, materials and resources, indoor environmental quality, innovation in design, and regional priority. Table 1 lists the seven categories of LEED-NC and their goals (USGBC 2010).
There are eight types of Sustainable Sites Credits (SSC): a) site selection, b) community connectivity, c) brownfield redevelopment, d) alternative transportation, e) site development, f) storm water design, g) heat island effect, and h) light pollution reduction. The SSC consist of 26 credits out of a possible 110 of LEED-NC. Among the types of SSC, this study focuses on Credit 4: Alternative transportation. Alternative transportation has 12 possible credits that are divided into four groups: a) Sustainable Site Credits (SSC) #4.1: Public Transportation Access (PTA), b) SSC #4.2: Bicycle Storage and Changing Rooms, c) SSC #4.3: Low-emitting and Fuel-efficient Vehicles, and d) SSC #4.4: Parking Capacity. The requirements for these credits are as shown in Table 2.

**PREVIOUS STUDIES**

As the need for environmental certification systems grows, Leadership in Energy and Environmental Design for New Construction (LEED-NC) is being widely adopted in the US to evaluate the environmental performance of buildings (Schedler and Udall 2005). However, according to Kibert, in terms of construction cost, LEED-NC will cause an increase of about $2 to $5 per square foot for office projects (Kibert 2005). Furthermore, since LEED-NC projects are complex systems, adopting LEED-NC requires higher level planning and monitoring (USGBC 2010).

In response, many researchers have attempted to examine the advantages of adopting the LEED criteria (Park 2009, Joshi 2009, Schedler and Udall 2005). Park found that some
LEED criteria (i.e., site selection, brownfield, and public transportation access) significantly affect the appraised unit value of parcels in Houston, Texas (Park 2009). As an extension of Park’s study, Joshi focused on the relationship between LEED PTA criteria and the appraised unit value of parcels (Joshi 2009). However, since Houston does not have a commuter rail system, it was not included in the two previous studies (Park 2009, Joshi 2009).

Although many researchers have attempted to examine the relationship between the distance to public transit and the appraised value of land, no research has been conducted regarding the relationship between the LEED-NC PTA criteria and the appraised land value in San Francisco County. To address this issue, this research focuses on whether or not the PTA, as part of the LEED-NC rating system, affects the appraised unit value of parcels. If the components of LEED-NC PTA criteria (number and distance from the parcel to transit nodes) affect the appraised unit value of parcels, then this could affect land development strategies.

**RESEARCH OBJECTIVES AND METHODS**

This study focuses on Public Transportation Access (PTA) criteria, which fall under the Sustainable Sites category (SS) of LEED-NC. Based on these criteria, the main objectives of this study are to a) investigate the impact of LEED-NC PTA on appraised land value in San Francisco County, and b) to develop a regression model that predicts the appraised unit value of parcels ($/ft^2$) based on

- the number of LEED-NC qualified bus, light rail, and commuter rail stations,
- distance to the closest bus, light rail, and commuter rail stations,
- zoning class, and
- parcel size.

According to the 2000 Census, San Francisco County is the sixth most densely populated county in the US, with 16,634.37 persons/mi^2 (2000) (Census 2000). It is also known to have one of the best-organized transit systems in the US (MTC 2010). Specifically, since San Francisco Municipal Railway (MUNI) began services in 1912, San Francisco County has

| Items | Requirements | Credits |
|-------|--------------|---------|
| SSC #4.1 Public Transportation Access (PTA) | Located within • ½ mile walking distance of commuter rail, light rail or subway station • ¼ mile walking distance of one or more bus stops on at least two bus routes | 6 |
| SSC #4.2 Bicycle Storage and Changing Rooms | Secure bicycle racks/or storage provided within 200 yards of a building entrance • Shower facilities in the building | 1 |
| SSC #4.3 Low-emitting and Fuel-efficient Vehicles | Preferred parking for low-emitting vehicles comprising 5% of the total vehicle parking capacity | 3 |
| SSC #4.4 Parking Capacity | Preferred parking for carpools comprising 5% of the total parking spaces | 2 |
been evaluated as having one of the richest public transportation systems (i.e., bus, light rail, and commuter rail systems) in US. Currently, its transit system is extensive; virtually every location in the city lies within a ¼ mile of a transit route (SFMTA 2010). Therefore, in order to investigate the impact of LEED-NC PTA criteria and the appraised unit value of parcels, San Francisco County was chosen because of its well-organized transportation systems.

In this study, based on the zoning code of San Francisco County, two multiple linear regression models were established for residential and mixed zones (Figure 1). First, residential and mixed zones were identified in San Francisco County. Second, based on LEED-NC PTA criteria, a LEED-NC PTA map using GIS was created to select LEED-NC PTA qualified parcels. Third, sample parcels’ information was collected to perform multiple linear regression analysis. After collecting data, Pearson’s correlation analysis among all variables and a multiple linear regression with one-way ANOVA were conducted to investigate the impact of LEED-NC PTA on the unit value of parcels in San Francisco County.

This study only focused on unimproved parcels in San Francisco County, California. Unimproved parcels were defined as those with zero improved land value on which there are no existing buildings. In addition, these unimproved parcels were not exempted from taxes. LEED-NC PTA criteria are typically assessed from a main building entrance to public transit nodes. However, unimproved parcels’ data were used in this study. The distance from the parcel centroid to public transit nodes was calculated using a GIS tool. Furthermore, this study only focused on mixed and residential zones planned by the San Francisco Planning Department. Other zones were not included in this study. Public land use was not included in this study.

HYPOTHESIS AND REGRESSION MODELS
To investigate the economic impact of LEED-NC PTA criteria on the appraised value of the land, the following three research hypotheses were tested:

- The appraised unit value of parcels in San Francisco County increases as the number of LEED-NC qualified bus, light rail, and commuter rail stations increases.
- The appraised unit value of parcels in San Francisco County increases as the distance to LEED-NC qualified bus, light rail, and commuter rail stations decreases.
- For the same parcel size, parcels in a mixed zone have a higher appraised unit value than those in a residential zone when they satisfy LEED-NC PTA criteria.
According to the zoning code, the following model was established in this study. The dependent variable, the appraised unit value of the parcel ($/ft^2$), can be predicted by the independent variables in mixed and residential zones as shown in Equation (1).

\[
UV_{(m,r)} = \beta_0 + \beta_1 \cdot NB_{(m,r)} + \beta_2 \cdot NL_{(m,r)} + \beta_3 \cdot NR_{(m,r)} + \beta_4 \cdot DB_{(m,r)} \\
+ \beta_5 \cdot DL_{(m,r)} + \beta_6 \cdot DR_{(m,r)} + \beta_7 \cdot AREA_{(m,r)}
\]

where
- \(m\): mixed zone
- \(r\): residential zone
- UV: Appraised unit value of an unimproved parcel
- NB: Number of bus stops within one-quarter mile from the parcel centroid
- NL: Number of light rail stations within a half mile from the parcel centroid
- NR: Number of rail stations within a half mile from the parcel centroid
- DB: Closest distance from the parcel centroid to a bus stop
- DL: Closest distance from the parcel centroid to a light rail station
- DR: Closest distance from the parcel centroid to a rail station
- AREA: parcel size (sqft)

**DATA COLLECTION METHODS**

This research focused on the PTA credits under the sustainable site category of LEED-NC. The requirements of the credits are to a) locate the project within one-half mile walking distance (measured from a main building entrance) of an existing or planned and funded commuter rail, light rail, or subway station; and to b) locate the project within one-quarter mile walking distance (measured from a main building entrance) of one or more stops for two or more public, campus, or private bus lines usable by building occupants. Therefore, spatial data are necessary to identify each parcel. The required spatial data can be obtained conveniently from websites of associated organizations as shown in Figure 2. Additionally, the appraised land value of each parcel in San Francisco County can be obtained from the Office of the Assessor-Recorder from the City and County of San Francisco website.

**FIGURE 2.** Spatial data required in this study.
SAMPLE SELECTION PROCESS

GIS is a system used to capture, retrieve, store, analyze, manage, and display data with spatial and attributive information (Bill 1994). Normally, spatial data shows the location and shape of geographic features using vector and raster layers. Vector data consist of points, polylines, and polygons. Raster data is a kind of digital image that contains information within a grid (Hellawell et al. 2001). The most powerful function of GIS is overlay. With this function, the user can produce new data layers by combining various kinds of existing data using the powerful analytical tools within GIS applications.

In this research, in order to collect and manage data for statistical analysis, GIS files retrieved from several sources were used. With these retrieved data, a LEED map was created to form new data. The population area of this study was defined as all parcels within San Francisco County as shown in Figure 3 (a). After identifying all parcels using GIS, all unimproved parcels were selected, which numbered approximately 4,800 (Figure 3 (b)).

![FIGURE 3. All parcels (a) and unimproved parcels (b) in San Francisco County.](http://meridian.allenpress.com/jgb/article-pdf/7/4/130/1771024/jgb_7_4_130.pdf)
CLASSIFYING SAMPLE PARCELS ACCORDING TO ZONING CODE

The zoning code of the City and County of San Francisco is established by Sections 105 and 106 of the Planning Code, which is a part of the San Francisco Municipal Code. In addition, zoning use districts are established by Sections 201, 702, 802 and 902 of the Planning Code (San Francisco Planning Department 2011). This study focused on parcels in residential districts, residential-mixed districts and residential-commercial combined districts. As shown in Table 3, there were 2,539 unimproved parcels zoned residential in September 2010 (California State Public Data 2011). In this research, 30% (762 parcels) of all residential unimproved parcels were randomly selected. There were a total of 273 unimproved parcels that were zoned mixed use and commercial, and 50% (137 parcels) of these parcels were randomly selected. Additionally, an acceptability standard to limit parcel selection to those parcels that were larger than a minimum allowed parcel size according to the zoning code was established.

### Table 3. Selected Sample Parcels from Residential and Mixed Districts.

| Zoning | Name of district                                      | Minimum size          | Number |
|--------|------------------------------------------------------|-----------------------|--------|
| RH-1   | Residential - Housing District, Single-Family        | Width: 25ft, Area: 2,500sq | 1,050  |
| RH-1 (D)| Residential - Housing District, Single-Family - Detached | Width: 33ft, Area: 4,000sq | 819    |
| RH-1 (S)| Residential - Housing District, Single-Family - Secondary Unit | Width: 25ft, Area: 2,500sq | 11     |
| RH-2   | Residential - Housing District, Two-Family           | Width: 25ft, Area: 2,500sq | 504    |
| RH-3   | Residential - Housing District, Three-Family         | Width: 25ft, Area: 2,500sq | 155    |
|        | Total                                                |                       | 2,539  |
|        | Selected Parcels                                     |                       | 762 (30%) |
| RM-1   | Residential - Mixed District, Low Density (Apartments and Houses) | Width: 25ft, Area: 2,500sq | 154    |
| RM-2   | Residential - Mixed District, Moderate Density (Apartments and Houses) | Width: 25ft, Area: 2,500sq | 35     |
| RM-3   | Residential - Mixed District, Medium Density (Apartments and Houses) | Width: 25ft, Area: 2,500sq | 22     |
| RM-4   | Residential - Mixed District, High Density (Apartments and Houses) | Width: 25ft, Area: 2,500sq | 42     |
| RC-3   | Residential - Commercial Combined District, Medium Density | Width: 25ft, Area: 2,500sq | 2      |
| RC-4   | Residential - Commercial Combined District, High Density | Width: 25ft, Area: 2,500sq | 18     |
|        | Total                                                |                       | 273    |
|        | Selected Parcels                                     |                       | 137(50%) |
MAPPING PUBLIC TRANSIT

As shown in Figure 4, the LEED-NC map includes all relevant public transportation assets in the population map. The public transit data, including location, latitude, altitude, and routes, were obtained from the Metropolitan Transportation Commission (MTC 2010). Figure 4 (a) shows all of the bus stops in 2010. These bus stops and routes include all three operators’ bus stops (SamTrans, GGT, and AC Transit). Light rail systems can be divided into three groups as shown in Figure 4 (b). The scope of this study included all stations of the MUNI light rail system, and cable cars and historic street cars served by the San Francisco Municipal Railway (MUNI). In terms of commuter rail systems, the BART and Caltrain rail systems were included in this study as shown in Figure 4 (c).

ECONOMIC IMPACT ASSESSMENT OF LEED-NC PTA

Relationship between Land Value and Qualified LEED-NC PTA Parcels

Table 4 shows the results of a Pearson’s correlation analysis performed to examine the relationships between the dependent variable (unit value of parcels) and the independent variables. The correlation between the unit value of parcels and the number of bus stops within one-quarter mile distance was assessed. In mixed and residential zones, there was a positive correlation between the two variables (p < 0.05). In addition, there was a significant negative correlation between the unit value of parcels and the closest distance from the parcel to a bus stop (p < 0.05). The unit value of parcels and the number of light rail stations within a distance of one-half mile were positively correlated (p = 0.05). However, in the mixed zone, the seemingly negative relationship between the unit value of parcels and the closest distance from a parcel to a light rail station represents was not significant (p > 0.05). Only the mixed zone exhibited a significant correlation between the unit value of parcels and the number of commuter rail stations within one-half mile (p < 0.05). However, in the mixed and residential zones there was no relationship between the unit value of parcels and the closest distance to a commuter rail station (p > 0.05), indicating that the proximity of a commuter rail system is not related to land value in residential zones. The correlation results are summarized below.

- For mixed zones, the appraised parcel value increases as the number of LEED-NC qualified transit stops increases (bus, light rail, and commuter rail).
- For residential zones, the appraised parcel value increases as the number of LEED-NC qualified bus and light rail stations increases.
- For mixed zones, the appraised parcel value increases as the distance to LEED-NC qualified bus stops and light rail stops decreases.
- For residential zones, the appraised parcel value increases as the distance to LEED-NC qualified bus stops decreases.

Diagnostics for Normality of Residuals and Transformation

In this study, multiple linear regression analysis with one-way ANOVA was performed to determine the impact of LEED-NC PTA on land value. This analysis was conducted separately for both the mixed and residential zones to establish a predictive model for land value. After transformation of the dependent variable using Box-Cox transformation to establish the best goodness of fit models, the residuals of the two models were found to be normally
FIGURE 4. LEED parcels selection process:
(a) bus
(b) light rail
(c) commuter rail system.
distributed and the p-values were less than 0.05 in the respective ANOVA tables. In addition, the Kolmogorov-Smirnov value confirmed that the residuals of the transformed model were normally distributed as shown in Figure 5 (c). Furthermore, a Q-Q plot and histogram of the standardized residuals also proved that the transformed model was normally distributed (Figures 5 (a) and (b)). Therefore, the absence of a heteroscedasticity problem and the robustness of the data were confirmed. In addition, the regression models were significant in testing hypothesis. The following transformation was used for the dependent variable:

\[
\text{Transformed } UV_m = (\text{Original } UV_m)^{0.1} \\
\text{Transformed } UV_r = (\text{Original } UV_r)^{0.3}
\]

### TABLE 4. Correlation Unit Value of Parcels vs. Independent Variables.

|                | Mixed zone |          | Residential zone |          |
|----------------|------------|----------|------------------|----------|
|                |            | Correlation Coefficient | R-square | P-value | Correlation Coefficient | R-square | P-value |
| Bus stop       | Number     | 0.682    | 0.465            | < 0.05   | 0.706    | 0.499    | < 0.05   |
|                | Distance   | -0.450   | 0.202            | < 0.05   | -0.340   | 0.116    | < 0.05   |
| Light rail     | Number     | 0.507    | 0.257            | < 0.05   | 0.612    | 0.374    | < 0.05   |
|                | Distance   | -0.371   | 0.138            | < 0.05   | -0.118   | 0.014    | > 0.05   |
| Commuter rail  | Number     | 0.378    | 0.143            | < 0.05   | 0.081    | 0.007    | > 0.05   |
|                | Distance   | -0.172   | 0.030            | > 0.05   | -0.078   | 0.006    | > 0.05   |

### FIGURE 5. Normality assessment of the transformed model for the mixed zone.
**The Transformed Model and its Validity**

Multiple linear regression analysis with backward elimination was used to select independent variables for the transformed model. Table 6 shows the coefficients of the predictive model for mixed zones. $\text{DR}_m$ was excluded from the predictive model since the p-value was higher than 0.05, while the other six independent variables were found to be significant predictors in the transformed model. In addition, there was no multi-collinearity problem associated with the predictive model since the variance inflation factor (VIF) ranged from 1.06 to 2.5 as shown in Table 5. The adjusted R-square of the transformed model was 0.713, which indicates that 71.3% of the variability in the transformed unit value of parcels could be explained by these variables.

Estimated coefficients of the predictive model for residential zones are given in Table 6. Three variables ($\text{NR}_r$, $\text{DL}_r$, and $\text{DR}_r$) were excluded since their p-values were higher than 0.05. The adjusted R-square for the model was 0.614, meaning that the independent variables together accounted for 61.4% of the variability in the transformed unit value of parcels. Furthermore, there was no multicollinearity problem since the VIF was less than 10.

Equations (2) and (3) were developed based on the coefficients identified in this study in order to determine how the unit value of the parcels can be affected by LEED-NC PTA and parcel size. Equation (2) represents the predictive model for mixed zones, and Equation (3) indicates the predictive model for residential zones. Equations (4) and (5) need to be retransformed to predict the unit value of the parcels as described by Equations (4) and (5).

\[
\begin{align*}
\text{UV}_m^{0.1} &= 1.339 + 0.027 \cdot \text{NB}_m + 0.036 \cdot \text{NL}_m + 0.013 \cdot \text{NR}_m - 0.751 \cdot \text{DB}_m \\
&+ 0.007 \cdot \text{DL}_m - 0.0008 \cdot \text{AREA}_m \\
\text{UV}_r^{0.3} &= 1.043 + 0.170 \cdot \text{NB}_r + 0.546 \cdot \text{NL}_r - 1.154 \cdot \text{DB}_r - 0.0006 \cdot \text{AREA}_r
\end{align*}
\]

**TABLE 5. Coefficients of the Transformed Model for Mixed Zones.**

| Variable | $\beta$ | Std. Error | t-value | p-value | VIF |
|----------|---------|------------|---------|---------|-----|
| (Constant) | 1.339 | 0.035 | 38.018 | <0.05 | 1.797 |
| $\text{NB}_m$ | 0.027 | 0.004 | 7.454 | <0.05 | 1.679 |
| $\text{NL}_m$ | 0.036 | 0.009 | 4.189 | <0.05 | 2.133 |
| $\text{NR}_m$ | 0.013 | 0.018 | 7.364 | <0.05 | 2.517 |
| $\text{DB}_m$ | -0.751 | 0.160 | -4.702 | <0.05 | 1.755 |
| $\text{DL}_m$ | 0.007 | 0.015 | 6.231 | <0.05 | 1.795 |
| $\text{AREA}_m$ | -0.0008 | 0.0001 | -5.342 | <0.05 | 1.069 |

**TABLE 6. Coefficients of the Predictive Model for Residential Zones**

| Variable | $\beta$ | Std. Error | t-value | p-value | VIF |
|----------|---------|------------|---------|---------|-----|
| (Constant) | 1.043 | 0.144 | 7.238 | <0.05 | 2.151 |
| $\text{NB}_r$ | 0.170 | 0.020 | 8.629 | <0.05 | 2.319 |
| $\text{NL}_r$ | 0.546 | 0.057 | 9.572 | <0.05 | 1.890 |
| $\text{DB}_r$ | -1.154 | 0.610 | -4.892 | <0.05 | 2.180 |
| $\text{AREA}_r$ | -0.0006 | 0.0001 | -5.342 | <0.05 | 1.011 |
\[ UV_m = [1.339 + 0.027 \cdot NB_m + 0.036 \cdot NL_m + 0.013 \cdot NR_m - 0.751 \cdot DB_m + 0.007 \cdot DL_m - 0.0008 \cdot AREA_m]^{(1/0.1)} \] (4)

\[ UV_r = [1.043 + 0.170 \cdot NB_r + 0.546 \cdot NL_r - 1.154 \cdot DB_r - 0.0006 \cdot AREA_r]^{(1/0.3)} \] (5)

**CONCLUSIONS**

The objective of this study was to develop a quantifying model that predicts the appraised unit value of parcels in San Francisco County based on the number of LEED-NC Public Transportation Access (PTA) qualified bus, light rail and commuter rail stops, the distance to the closest bus, light rail and commuter rail stops, zoning class, and parcel size. As a population of interest, San Francisco County was chosen since it is known to have well-organized transportation systems including bus, light rail, and commuter rail systems.

According to the correlation results, for mixed zones, the appraised unit value increased as the number of LEED-NC qualified transit stops increased (bus, light rail, and commuter rail). In addition, the appraised unit value increased as the distance to LEED-NC qualified bus stops and light rail stops decreased. For residential zones, the appraised unit value increased as the number of LEED-NC qualified bus and light rail stations increased. Furthermore, the appraised unit value increased as the distance to LEED-NC qualified bus stops decreased.

When it came to the predictive regression model for mixed zones, the adjusted R-square of the transformed model was 0.713, which indicates that 71.3% of the variability in the transformed unit value of parcels could be explained by these variables. In addition, for the predictive model for residential zones, the adjusted R-square for the model was 0.622, indicating that the independent variables together accounted for 62.2% of the variability in the transformed unit value of parcels.

The predictive models for the mixed and residential zones were significant, suggesting that the components of the LEED-NC PTA criteria could affect land development strategies. In addition, the appraised unit value of parcels in San Francisco County can be estimated using the predictive models developed in this study. Therefore, the findings of this study could encourage real estate developers to site their projects according to the LEED-NC PTA criteria.

**FUTURE STUDY**

The adjusted R-square was 0.713 and 0.622 for the models of the mixed and residential zones, respectively. This indicates that there are some unknown factors not accounted for in the regression models. Therefore, to identify the best fit models for predicting the appraised unit value of parcels in San Francisco County, other possible variables such as additional LEED criteria, household income, education level, etc., should be examined.

This study only focused on the appraised land value of unimproved parcels in San Francisco County. Therefore, the findings of the study are not applicable to improved parcels and other areas. If future research is extended to improved land value using reliable data, then the findings could be useful for developers trying to predict the appraised land value of parcels. In addition, this study focused on mixed and residential zones. Commercial zones were not considered in this study. Therefore, it is necessary to examine the impact of LEED-NC PTA on the appraised unit value of parcels for commercial zones.
In addition, the process using GIS developed in this study can be applied to other cities such as Portland and Seattle to predict their appraised unit value of parcels. Portland and Seattle ranked first and third, respectively, in terms of the number of LEED-NC projects according to US city sustainability rankings (People-Powered Sustainability Guide 2011). Therefore, the models developed in this study could be used to more accurately investigate the economic impact of LEED-NC criteria on the appraised unit value of parcels in these cities.

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