REGRESSION MODEL PREDICTING APPRAISED UNIT VALUE OF LAND IN SAN FRANCISCO COUNTY FROM NUMBER OF AND DISTANCE TO PUBLIC TRANSIT STOPS USING GIS

A Dissertation

by

KIYOUNG SON

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

DOCTOR OF PHILOSOPHY

May 2012

Major Subject: Architecture

Regression Model Predicting Appraised Unit Value of Land in San Francisco County

from Number of and Distance to Public Transit Stops Using GIS

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Approved by:

Co-Chairs of Committee,	Paul K. Woods
	Valerian Miranda
Committee Members,	F. Michael Speed
	Lavy Sarel
Head of Department,	Ward Wells

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ABSTRACT

Regression Model Predicting Appraised Unit Value of Land in San Francisco County from Number of and Distance to Public Transit Stops Using GIS. (May 2012)

Kiyoung Son, B.A., Kyunghee University; M.S., Kyunghee University

Co-Chair of Advisory Committee: Dr. Paul K. Woods
Dr. Valerian Miranda

The objective of this study is to develop a quantifying model that predicts the appraised unit value of parcels in San Francisco County based on number of LEED-NC Public Transportation Access (PTA) qualified bus, light rail and commuter rail stops, distance to 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 as a region having well-organized transportation systems including bus, light rail and commuter rail systems.

According to the correlation results, for mixed zone, an appraised unit value increases as the number of LEED qualified transit stops increases (bus, light rail, and commuter rail). In addition, the appraised unit value increases as the distance to LEED qualified bus stops light rail stops decreases. For residential zone, the appraised unit value increases as the number of LEED qualified bus and light rail stations increases. Furthermore, the appraised unit value increases as the distance to LEED qualified bus stops decreases.

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

The predicting models for mixed and residential zones were significant that suggests that the components of LEED-NC PTA criteria, number and distance from parcels, this could affect land development strategies. In addition, an appraised unit value of parcels in San Francisco County can be estimated by 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.

DEDICATION

To Dr. Paul K. Woods, my revered teacher

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I would like to thank my co-chairs, Dr. Woods and Dr. Miranda, and committee members, Dr. Speed, and Dr. Lavy for their guidance and support throughout the course of this research.

Thanks also to my friends and colleagues and the department faculty and staff for making my time at Texas A&M University a great experience. I also want to extend my gratitude to the Kyunghee University in Korea. Especially, I appreciate Mrs. Carleen Cook my editor. Thanks also to Young Jun Park and Ji-myong Kim who assisted with my dissertation. Finally, thanks to my father, mother, and younger brother for their encouragement and support.

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1. INTRODUCTION

1.1 Backgound

As needs grow for environmental certification systems, Leadership in Energy and Environmental Design for New Construction 3.0 (LEED-NC 3.0) is being widely adopted in the U.S to evaluate the environmental performance of buildings (Schedler and Udall 2005). However, according to Kilbert, using LEED-NC will cause an increase of about $2 to $5 per square foot to the construction costs for office projects (Kilbert 2005).

Furthermore, since LEED-NC projects are complex systems with several different types of costs (i.e: cost of documentation time and effort, cost of extra research and design, cost of commissioning and modeling for compliance, costs of construction, and cost of LEED reports), adopting LEED-NC requires additional planning and monitoring costs (Howe 2010).

In response, many researchers have attempted to examine the advantages of adopting the LEED (Park 2009, Joshi 2009, Howe 2010). Park conducted a study to identify the impact of some LEED criteria (i.e.: site selection, brownfield, and public transportation access) on appraised unit value of parcels in Houston. Park concluded that the LEED criteria are significantly related to appraised unit value of parcels in Houston (Park 2009).

This dissertatoin follows the style of the *Journal of Construction Engineering and Management.*

As an extension of Park's study, Joshi focused on the relationship between LEED Public Transportation Access (PTA) criteria and appraised unit value of parcels (Joshi 2009). However, since Houston does not have commuter rail system, among LEED PTA criteria, commuter rail systems was not included in two previous studies (Park 2009, Joshi 2009).

Many researchers have investigated the factors related to appraised land value. The research can be placed in two categories. First, researchers have examined the impact of land use such as parks and wetlands and views of water-covered areas on appraised land value (Lutzenhiser and Netusil 2001, Schultz and King 2001, Baranzini and Schaerer 2011). Second, researchers have investigated the impact of public transit nodes in various areas on appraised land value (Cevero and Duncan 2004, Landis et al 1995, Gatzlaff and Smith 1993).

Although many researchers have examined the relationship between many variables and appraised land value, no research has been conducted regarding the relationship between the LEED-NC Public Transportation Access (PTA) criteria and 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 appraised unit value of parcels of vacant land.

If this research established that the components of LEED-NC PTA criteria (number and distance from parcel to transit nodes) affect appraised unit value of parcels, then this could affect land development strategies. Furthermore, if the results of the San Francisco study are similar to the Houston studies, outcomes of both studies (Joshi 2009, Park 2009) would be strengthened.

1.2 Research Objectives

This study focuses on Public Transportation Access (PTA) criteria that 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 unit value of land in San Francisco County, and b) develop a regression model that predicts the appraised unit value of parcels of land ($/sqft) followed by:

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

According to Census 2000, San Francisco County is the sixth most densely populated county in the U.S (Census 2000). It is also known as a region having well-organized transportation systems (i.e.: bus, light rail, and commuter rail systems) in U.S. (MTC 2010). Therefore, in order to investigate the impact of LEED-NC PTA criteria and appraised unit value of parcels, San Francisco County was chosen for this study because of its well-organized transportation systems.

1.3 Organization of the Dissertation

This section has discussed the background and the objectives of this study. Section 2 surveys the importance and limitations of the LEED rating system and also discusses previous studies in the area regarding the factors relating to appraised land value. In addition, appraised land values of San Francisco County are defined. Finally, this section describes how these values are used in this study. Section 3 describes the methodology applied in this study as well as its hypotheses and limitations.

Section 4 discusses how the information to identify each parcel of the population in San Francisco County was collected from spatial data using Geographic Information System (GIS).

Section 5 discusses the statistical analysis of collected data from the previous section including correlation results as well as the regression analysis established in this study. Finally, Section 6 summarizes the findings of this study and presents conclusions and recommendations.

2. LITERATURE REVIEW

This section is divided into four parts to provide the basis of development of this study. First, the importance of the LEED-NC rating system is discussed. Second, the public transit nodes in San Francisco County are discussed as the population of interest of this study. Third, the previous studies regarding the factors related to appraised land value are reviewed. Finally, appraised land values of San Francisco County are defined.

2.1 Growing Need for Environmental Certification Systems

The construction industry has been 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 (Howe 2010). In addition, the residential and commercial construction sectors alone consume approximately 38% of 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 U.S 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 for sustainable development in buildings. Therefore, in recent years, to encourage sustainable development, environmental certification systems such as Green Star (Australia), Leadership in Energy and Environmental Design (LEED) (U.S), Energy Star (U.S), and Green Globes (U.S) have been developed.

2.2 LEED Green Building Rating System

Leadership in Energy and Environmental Design (LEED) is considered one of the most favored sustainability rating systems in the U.S (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 nine rating systems such as 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 U.S have been certified by LEED-NC (USGBC 2010). This LEED-NC is designed to guide and distinguish high-performance commercial and institutional projects such as 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).

2.3 LEED-NC Public Transportation Access (PTA)

LEED-NC is defined as the leadership position for designing and building commercial, institutional, government buildings and high-rise residential building 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).

This LEED-NC addresses the environmental impacts of site and materials selection, demolition, and construction. Since its launch in 2000, over 4,000 building projects have certified for LEED-NC in the U.S. (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 such as Sustainable sites, water efficiency, energy and atmosphere, materials and resources, indoor environmental quality, innovation in design, and regional priority. Table 1 represents the seven categories of LEED-NC and their goals.

Table 1. Seven Categories of LEED-NC

No.	Category	Goal	Credits
1	Sustainable Sites	- Develop only appropriate sites - Reuse existing buildings and or sites - Protect natural and agricultural areas - Reduce need for automobile use - Protect/restore natural sites	26
2	Water efficiency	- Reduce the quantity of water needed for the building - Reduce municipal water supply and treatment burden	10
3	Energy and atmosphere	- Establish energy efficiency and system performance - Optimize energy efficiency - Encourage renewable and alternative energy sources - Support ozone protection protocols	35
4	Materials and resources	- Use materials with less environmental impact - Reduce and manage waste - Reduce the amount of materials needed	14
5	Indoor environmental quality	- Establish good indoor air quality - Reduce and manage indoor air pollution - Ensure thermal comfort and systems controllability - Provide the outdoor environment to occupants	15
6	Innovation in design	- Recognize exceptional performance - Recognize innovation in green building categories not specifically addressed by LEED-NC credits	6
7	Regional priority	- Provide an incentive for geographically-specific environmental priorities	4

Among them, in Sustainable Sites Credits (SSC), there are 8 credits such as 1) site selection, 2) community connectivity, 3) brownfield redevelopment, 4) alternative transportation, 5) site development, 6) storm water design, 7) heat island effect, and 8) light pollution reduction. This SSC consists of 26 credits out of 110. Among SSC, this study has focused on credit 4 Alternative Transportation as shown in Figure 1.

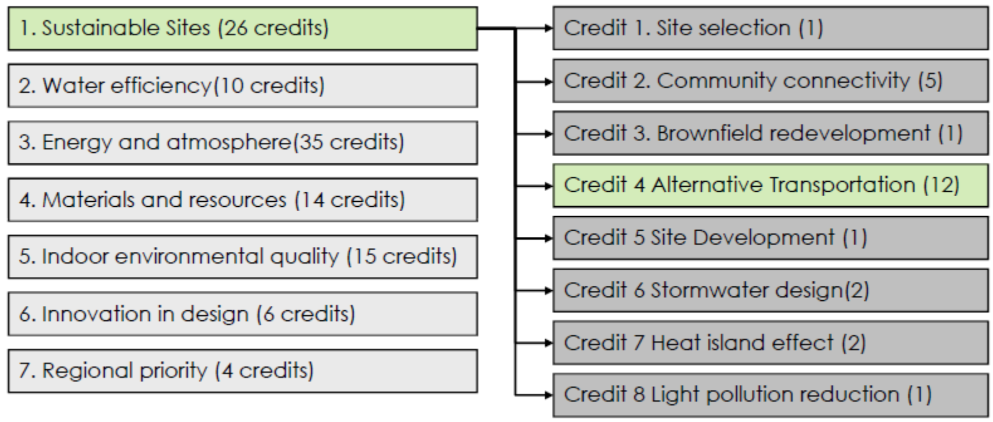


Figure 1. LEED-NC seven topics and sustainable sites category

The credit 4 Alternative Transportation has 12 credits which are divided into the four following groups. 1) Sustainable Site Credits (SSC) #4.1: Public Transportation Access (PTA), 2) SSC #4.2: bicycle storage and changing rooms, 3) SSC #4.3: low-emitting and fuel-efficient and 4) SSC #4.4: parking capacity. As shown in Table 2, the requirements of these credits are as follows:

Table 2. SSC 4: Alternative Transportation

Items	Requirements	Credits
SSC #4.1 Public Transportation Access (PTA)	Locate within - ½ mile walking distance of commuter rail, light rail or subway station - ¼ mile walking distance of 1 or more bus stops on at least 2 bus routes	6
SSC #4.2 Bicycle storage and changing rooms	- Provide secure bicycle racks/or storage within 200 yards of a building entrance - Provide shower facilities in the building	1
SSC #4.3 Low-emitting and fuel-efficient	- Provide preferred parking for low-emitting vehicles for 5% of the total vehicle parking capacity	3
SSC #4.4 Parking capacity	- Provide preferred parking for carpools for 5% of the total parking spaces	2

2.4 San Francisco Public Transit

San Francisco County is the sixth most densely populated County in the U.S, with 16,634.37 persons/sqmi (2000) (Census 2000). It is also known as having a one of the best-organized transit systems in the U.S. (MTC 2010). In detail, since San Francisco Municipal Railway (MUNI) began services in 1912, San Francisco County has been evaluated as having a rich public transportation system. Currently, its transit system is extensive; virtually every location in the city lies within a ¼ mile of a transit route (SFMTA 2010). The transit system in San Francisco County is complex, with several types of services offered by different local and regional operators. These are described the following sections.

2.4.1 Regional Bus Operators

Three bus operators provide service to San Francisco from neighboring counties. First, San Mateo County Transit District (SamTrans) is a public transport agency in the San Francisco Bay Area. SamTrans offers six commuter express routes and two intercity routes into San Francisco from San Mateo County (Dunn 2010). Second, Gloden Gate Transit is a public transportation system serving the North Bay region of the Bay area. It offers five basic routes and 19 commuter routes into and out San Francisco from Marin and Sonoma counties and service is operated 21 hours a day (GGT 2011). Third, Alameda-Contra Costa Transit District (AC Transit) operates “transbay” routes across the San Francisco Bay area to San Francisco and selected areas in San Mateo and Santa Clara Counties. AC Transit offers service from the East Bay on 23 routes, with many of these routes having variations. Four AC Transit are operated on the weekends, and AC Transit offers some 24-hour service (MTC 2010).

2.4.2 San Francisco MUNI

The primary transit operator within San Francisco is the San Francisco Municipal Railway (MUNI) (MTC 2010). In 2006, it served 46.6 square miles with an operating budget of about $700 million (Bose 2009). MUNI operate the largest fleet of buses, trolleybuses and motor coaches, light rail vehicles, historic trolley cars, and cable cars west of the Mississippi River. MUNI service operates seven days a week and several routes run for 24-hours a day. In 2010, its network consists of 54 bus lines, 17 trolley bus lines, seven light rail lines that operate above ground and in the City's only subway tube (called Muni Metro), three cable car lines, and a heritage streetcar line known as the F Market & Wharves (SFMTA 2010). Figure 2 represents the MUNI system map including cable car, a heritage streetcar and light rail system.

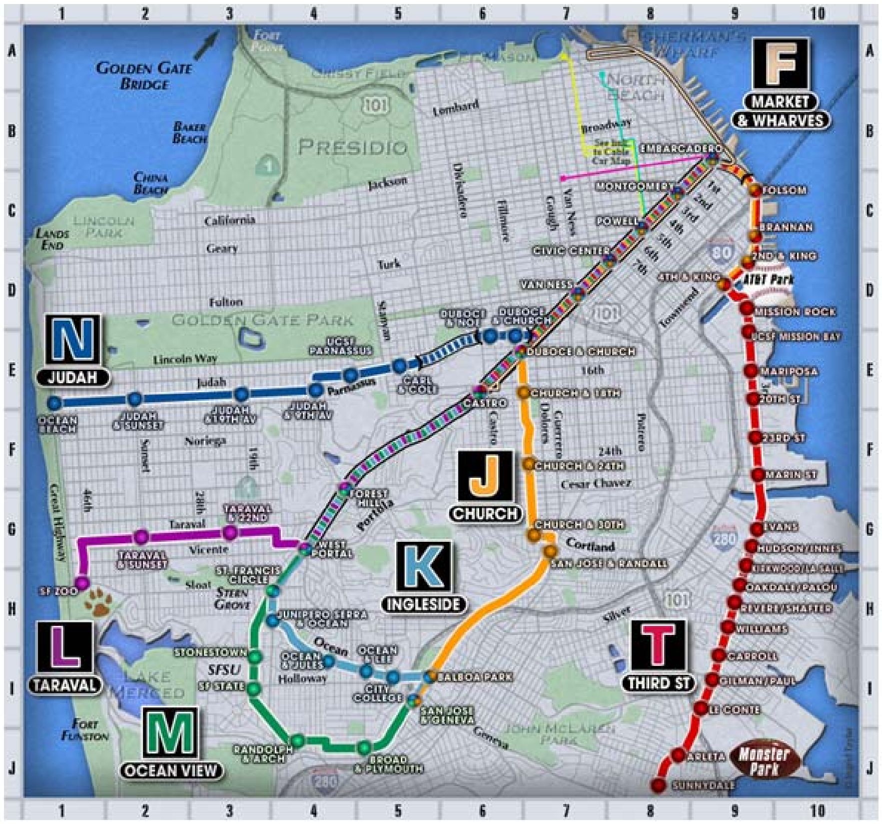


Figure 2. San Francisco County MUNI map
Source: sanfrancisco.about.com

2.4.3 Bay Area Rapid Transit: BART

Bay Area Rapid Transit (BART) is a commuter rail system serving the San Francisco Bay Area. BART connects San Francisco to Alameda and Contra Costa Counties to the east and San Mateo County to the South. BART operates services to eight San Francisco stations daily with average weekday ridership of 341,151 passengers in 2010 (BART 2011). BART trips that occur entirely within San Francisco County account for approximately 10% of all internal transit trips. It demonstrates that BART is a significant provider of local rail service, in addition to regional service (SFMTA 2010).

2.4.4 Caltrains

The Caltrain commuter rail system operates between Giloy and San Francisco and served about 5,900 boarding per day in 2000 connected to four stations in the city such as 4^{th} & King Street, 22^{nd} Street, Bayshore, and South San Francisco station (SFMTA 2010). The current terminus at 4^{th} and King Streets is served by MUNI buses and N-line Muni METRO (light rail) service. Average weekday ridership in February 2011 was 41,442 persons per day, up 12.7% from February, 2010 (Caltrain 2011).

Caltrain has direct connections to three regional rail services; Bay Area Rapid Transit (BART) (with service to San Francisco, SFO, Oakland, Fremont, Richmond, Dublin, Concord, and Pittsburg.) at the Millbrae Intermodal Station, Amtrak's Capitol Corridor and Coast Starlight trains, as well as Altamont Commuter Express at San Jose's Diridon Station. The future BART-to-San Jose extension would also introduce connecting BART service at Diridon station and Santa Clara station. Planned renovation for the Santa Clara station would also reintroduce the possibility of connecting service for Altamont Commuter Express and Amtrak (Caltrain 2011).

2.5 Previous Studies

Many researchers have investigated the factors related to appraised land value. First, researchers have examined the impact of land use such as parks and wetlands and views of water-covered areas on appraised land value (Lutzenhiser and Netusil 2001, Schultz and King 2001, Baranzini and Schaerer 2011). Second, researchers have investigated the impact of public transit nodes in various areas on appraised land value (Cevero and Duncan 2004, Landis et al 1995, Gatzlaff and Smith 1993). Third, researchers have investigated the impact of the LEED rating system on appraised land value in Houston. The following sections describe the impact of diverse variables such as land use, views, public transit nodes and the LEED rating system on appraised land value.

2.5.1 The Impact of Land Use on Appraised Land Value

Urban parks and forests, water resorts, lake shores, farmlands and land use affect residential zones because these provide opportunities for recreation, relief from urban stresses and congestion (Baranzini and Schaerer 2011). Benson et al have investigated how views from homes affect the land value in residential areas (Benson et al. 1998). Geoghegan investigated the value of open spaces in residential land use (Geoghegan 2002). Irwin also concluded that open spaces within 1 km positively affect residential property value (Irwin 2002). Seiler et al investigated the impact of lake views on residential property values (Seiler et al. 2001).

According to the study of Baranzini and Schaerer, parks significantly affect residential rent in Geneva, Switzerland. In particular, the size and view of the natural environment increased residential rents while the developed environmental views negatively affected the rents. The researchers concluded that residential rents in Geneva increased by 57% for a view of water-covered areas while the surface of agricultural areas in the neighborhood of the building and industrial areas did not have a significant impact on residential rents (Baranzini and Schaerer 2011).

Lutzenhiser and Netusil investigated the impact of parks on housing prices in Portland, Oregon. The researchers concluded that housing prices near parks are more expensive with prices increasing based on park size (Lutzenhiser and Netusil 2001). Batemen et al used GIS application to investigate the impact of noise and visual intrusion of road development on residential property prices (Bateman et al. 2001). Yu et al also measured the impact of view of sea on real estate prices (Yu et al. 2007).

Therefore, although many researchers have investigated the factors related to appraised land value, no research has been conducted to the impact of LEED PTA criteria on appraised land vale in San Francisco County.

2.5.2 The Impact of Public Transit Nodes on Appraised Land Value

Cervero and Duncan studied the impact of public transit such as commuter rail, light rail, and bus rapid transit on appraised land value in Los Angeles County. The data were divided into four groups such as single, multi-family housing, condominiums, and commercial buildings. The land value of approximately 30% of the parcels was examined within 0.5 mile of public transit (Cevero and Duncan 2004). Figure 3 shows the results of the study which represent the effects of proximity of bus, light rail, commuter rail transit on commercial land value.

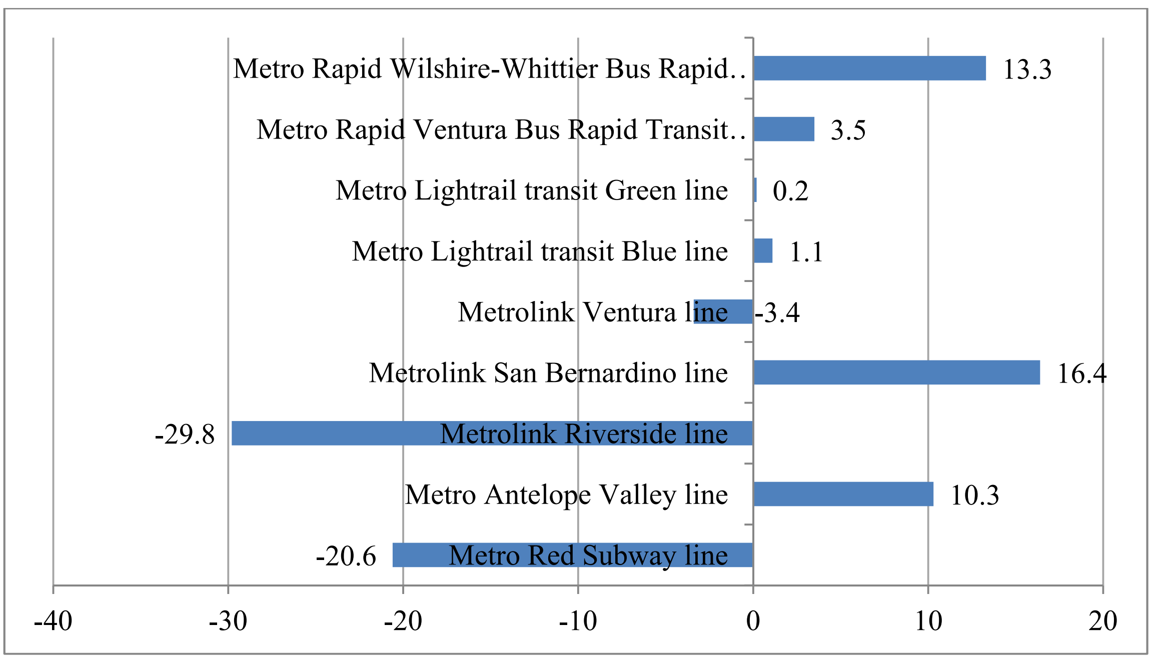


Figure 3. Commercial land value premiums or discounts in Los Angeles County

In addition, a survey of the existing literature shows that while there have been many research studies examining impact of transit stations on appraised land value (Cevero and Duncan 2004; Landis et al 1995; Gatzlaff and Smith 1993), no research has been conducted to determine the extent to which LEED Public Transportation Access (PTA) components might further impact land values as shown in Table 3.

Table 3. Summary of Existing Literature

Type	**Author (year)**	**Impact**	**Location (Transit facility)**	**Criteria (within)**
Heavy rail	Cervero and Duncan (2004)	Negative	Los Angeles, California (Metro Red Line)	Housing price (one-half mile)
	Landis et al (1994)	Negative	San Mateo County (CalTrain)	Single-family(500 feet)
	Gatzlaff and Smith (1993)	Neutral	Dade County, Florida (The Miami Metrorail system)	Housing price (one-quarter mile)
Light rail	Landis et al (1994)	Negative	San Jose (Light rail)	Single-family(500 feet)
		Neutral	Sacramento (Light rail)	Single-family(500 feet)
Bus	Cervero and Duncan (2004)	Negative	Los Angeles, California (Bus Rapid Transit Red Line)	Housing price (one-half mile)
Heavy rail	Cervero (1998)	Positive	Tokyo, Japan (The Tokaido line)	Commercial parcels (165 feet)
	McMillen and McDonald (2004)	Positive	Chicago, Illinois (The Midway Rapid Transit Line)	Housing price (one block)
Light rail	Cervero and Duncan (2004)	Positive	Los Angeles, California (Metrolink)	Housing price (one-half mile)
Bus	Cervero and Duncan (2004)	Positive	Los Angeles, California (Bus Rapid Transit Blue Line)	Condominium (one-half mile)

Therefore, although many researchers conducted to investigate the impact of transit nodes on appraised unit value of parcels (Cevero and Duncan 2004; Landis et al 1995; Gatzlaff and Smith 1993), no research has been conducted regarding the relationship between the LEED-NC PTA criteria and appraised unit value of parcels in San Francisco County.

2.5.3 The Impact of LEED Rating System on Appraised Land Value

Park conducted a study for identifying the relationship between LEED criteria (i.e.: site selection, brownfield, and public transportation access) and appraised unit value of parcels in Houston. In the study, the LEED PTA criteria were found significant factors associated with an increase in the appraised unit value of parcels within Houston (Park 2009).

As an extension of Park's research, Joshi's study quantified the impact of LEED PTA criteria components on the appraised unit value of parcels in Houston using a multiple linear regression. The regression model was established to predict appraised unit value of parcels in Houston. The dependent variable was appraised unit value of parcels ($/sf) and the independent variables are number of bus stops and number of light rail stations that meet LEED criteria and area of given parcels.

Joshi first collected data for sample parcels in Houston from the Harris County Appraisal District website, then analyzed the data through statistical methods including correlation and multiple regression analysis to predict appraised unit value of these parcels. The regression model is as follows:

Predicted appraised unit value of parcels in Houston = $[1.873 - 0.015\,(\text{Num Bus Stops}) + 0.426\,(\text{Num Rail Stations}) - 0.000002522\,(\text{area})]^{(1/0.3)}$

According to results, an increase in the number of light rail stations led to an increase in the appraised unit value of a parcel while the number of LEED qualified bus stops negatively affected the appraised unit value of parcels in Houston (Joshi 2009).

Joshi's study focused only on the number of bus stops and light rail stations since Houston has no commuter rail stations (Joshi 2009). To address this issue, this research focuses on whether or not the PTA including bus, light rail and commuter rail system, as part of the LEED-NC rating system, affects appraised unit value of parcels.

Therefore, although many researchers have attempted to examine the relationship between public transit modes and appraised land value, no research has been conducted regarding the relationship between LEED-NC PTA criteria and appraised land value in San Francisco County.

2.6 Market Value vs. Appraised Value of Land in San Francisco County

Both market value and appraised value are used in the dealings of land, residential homes, commercial property, retail buildings, and farms. However, there are differences between the market value and appraised value. Market values are consumer-driven and appraised values are decided by experts (Castro 2011).

Appraised values are based on gathered data and judgment of the professionals conducting the appraisal. The market value has more variance than the appraised value. Unlike the appraised value, buyers influence the market value of a property because a property is only worth what a buyer is willing to pay (Rubenstein 2011).

An appraiser establishes the appraised value based on recent property sales in the neighborhood, the condition of the land and a number of other details such as its features and functionality while market value can be determined by either licensed or unlicensed individuals. In most cases, the appraised value overrides the market value (Guerra 2011).

If the market value is calculated by a licensed real estate agent, the report includes active property listings, pending property sales, sold properties in the last 12 months and expired listings (Bramble 2011). However, for appraised value, an appraiser determines the property's appraised value. Appraisers do not represent an individual's interests regarding a property (Bramble 2011).

Unlike the market value, the appraised value is not necessarily the price a property will be bought or sold for. Rather it is a guideline for the selling or buying process (Castro 2011). Generally, a property will not be sold for more than the appraised value, especially if a lender is financing the purchase. However, the property may, in reality, be worth more than the appraised value to a buyer and a seller.

Additionally, appraisal reports are used for various purposes such as insurance, home loans, tax loss, estates, liquidation and net worth. Therefore, this study focuses on appraised value of land to investigate the economic impact of public transit on vacant land in San Francisco County.

3. RESEARCH METHODOLOGY

In order to predict appraised unit value of land parcels in San Francisco County, this study is divided into three parts:

1) Data collection by using GIS
2) Mixed zone regression model analysis
3) Residential zone regression model analysis

3.1 Data Collection Process

Figure 4 represents research methodology. To achieve the objective of this study, first, all unimproved parcels were identified according to the zoning code for mixed and residential zones. Second, in order to collect data, public transit modes were mapped including bus, light rail, and commuter rail stations. Third, LEED-NC PTA qualified parcels were randomly selected and sample parcels information was collected. After collecting data, the regression models were established and analyzed.

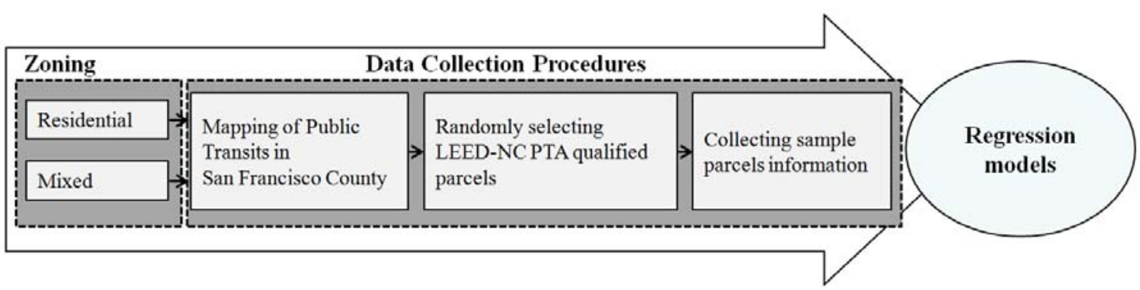


Figure 4. Data collection procedures

3.2 Data Analysis Process

In order to accomplish the objectives of this study, each statistical technique was applied to two distinct data samples. The data collection of this study used GIS tools to create both the mixed use and residential samples of LEED-NC PTA qualified parcels. Subsequently, the following statistical methods were applied.

1. Descriptive analysis (i.e: standard deviation, variance, and mean of variables) to provide simple summaries about the samples. This analysis forms the basis of the quantitative analysis of data.
2. Scatter plots between dependent and independent variables. This visually shows any relationship among variables.
3. Pearson's correlation analysis to identify relationships among all variables.
4. ANOVA test for models to check for significant differences among means of variables.
5. Normality check of residuals to determine whether or not data is well-modeled by a normal distribution.
6. Box-Cox analysis to obtain appropriate values if transformation of data is necessary.
7. Co-linearity analysis of the independent variables in the multiple linear regression models to identify whether or not the variables are highly correlated.

3.3 Research Hypothesis

To achieve the objective of this study, the following three research hypotheses were tested.

- The appraised unit value of parcels of vacant land 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 of vacant land in San Francisco County increases as the distance to LEED-NC qualified bus, light rail, and commuter rail stations decreases.
- At the same parcel size, mixed zone has higher appraised unit value of parcels than residential zone when the parcels satisfy LEED-NC PTA criteria.

According to the zoning code, following models were established in this study. The dependent variable, appraised unit value of the parcel of vacant land ($\$/ft^2$), can be predicted by the independent variables in mixed and residential zones as shown in Equation (1).

$$UV_{(m,r)} = \beta_0 + \beta_1 \cdot NB_{(m,r)} + \beta_2 \cdot NL_{(m,r)} + \beta_3 \cdot NR_{(m.r)} + \beta_4 \cdot DB_{(m,r)} + \beta_5 \cdot DL_{(m,r)} + \beta_6 \cdot DR_{(m.r)} + \beta_7 \cdot AREA_{(m,r)} \quad (1)$$

where,

m : mixed zone

r : residential zone

UV : Appraised unit value of unimproved parcel

NB : Number of bus stops within one-quarter mile from the parcel centroid

NL : Number of light rail stations within half mile from the parcel centroid

NR : Number of rail stations within half mile from the parcel centroid

DB : Closest distance from the parcel centroid to bus stop

DL : Closest distance from the parcel centroid to light rail station

DR : Closest distance from the parcel centroid to rail station

AREA : parcel size (sqft)

3.4 Assumption

The four following assumptions were established in this study.

- The LEED-NC will continue as the most popular criteria for evaluation environmental performance of buildings in the U.S because, currently, the LEED-NC is the most popular criteria in the U.S since its original inception in 1998.
- Land parcel information acquired from the San Francisco government website is accurate since it is official record.
- The appraised value of parcel is accurate since, as official records, the value is the basis for property tax assessed by the office of the Assessor-Recorder of San Francisco County.
- Appraised unit value of parcels of land is an indicator reflecting economic value of land.

- Data of public transit nodes of San Francisco County are reliable since these are regularly updated by the Metropolitan Transportation Commission (MTC), an official government department.

3.5 Delimitations

This study focused only on unimproved parcels in San Francisco County, California because it is difficult to calculate both housing prices and land values separately. In addition, these unimproved parcels were not exempted from taxes.

LEED-NC PTA criteria are measured from a main building entrance to public transit nodes. However, because unimproved parcels data were used in this study, buildings do not exist on the parcels. Therefore, the distance from parcel centroid to public transit nodes was measured by using GIS instead of a main building entrance.

This study focused only on mixed and residential zones planned by San Francisco planning department. Other zones were not included in this study. In addition, public land use was not included in this study.

3.6 Definitions

Parcel: A plot of land which owned, sold, and developed as shown in the records of the city.

Unimproved parcel: the parcel with zero improved land value where buildings do not exist on the parcel.

Appraised unit value of an unimproved parcel: the unit value, in U.S dollars per square foot, for an unimproved parcel.

Zoning use districts in San Francisco County: the districts planned by San Francisco Planning Department.

4. DATA COLLECTION

4.1 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 1) 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 2) 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, in order to assess each parcel, spatial data are necessary. The required spatial data can be obtained conveniently from websites of associated organizations as shown in Figure 5. 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.

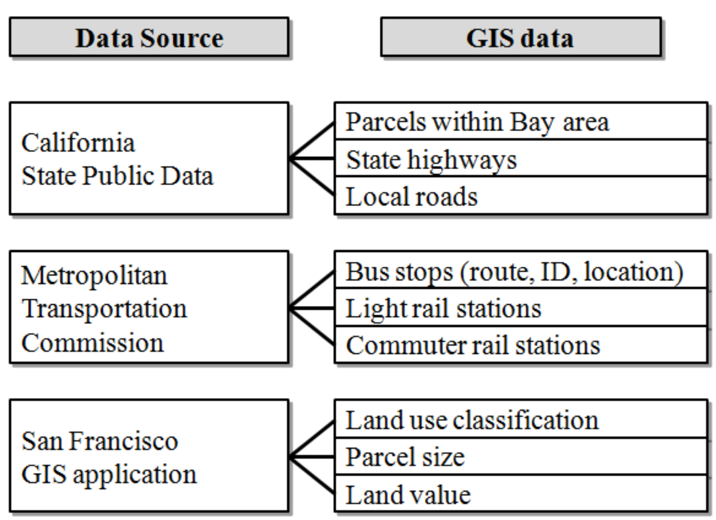
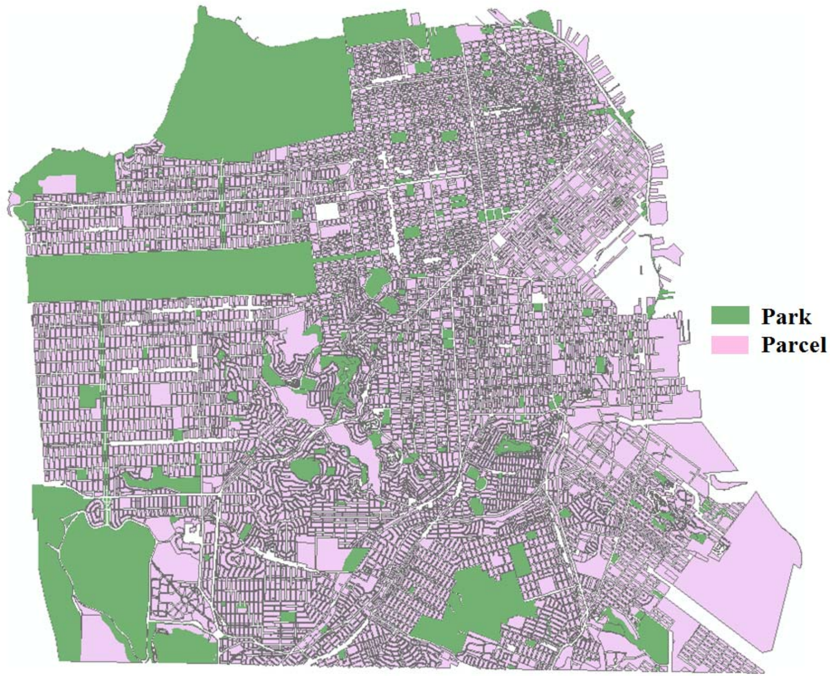


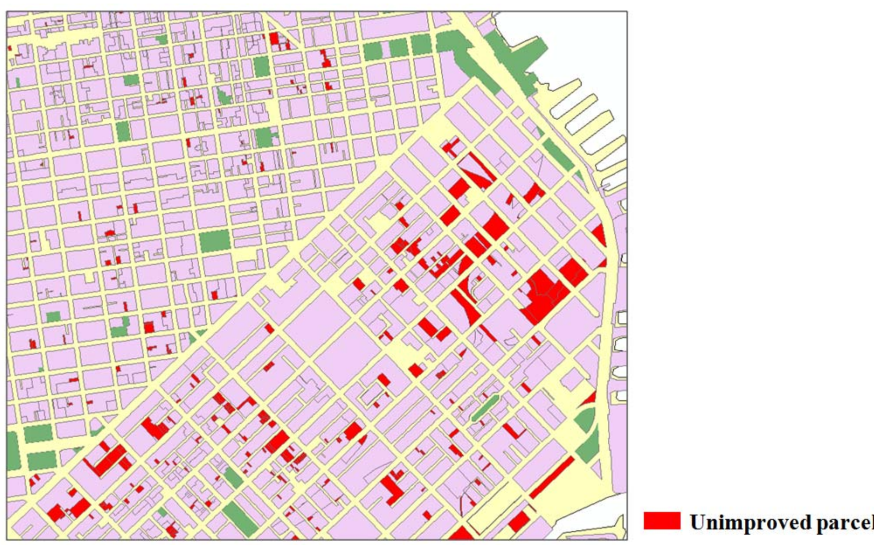
Figure 5. Spatial data required in this study

4.2 Sample Selection Process

GIS is the 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 data using vector and raster data on each layer. Vector data consists 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 the 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, the LEED map was created to form new data. The population area of this study is defined as all parcels, which were within San Francisco County as shown in Figure 6 (a). After identifying all parcels through using GIS, all unimproved parcels were selected and these numbered approximately 4,800 parcels (see Figure 6 (b)).



(a)



(b)

Figure 6. All parcels (a) and unimproved parcels (b) in San Francisco County

4.2.1 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). Table 4 represents all zoning codes of San Francisco County. Among them, this study is limited to residential, mixed and residential-commercial combined district.

Table 4. Zoning Use Districts

Public		Chinatown Mixed Use Districts	
P	Public	CRNC	Residential/ commercial
Residential, House Character Districts		CVR	Visitor retail
RH-1 (D)	One unit per lot, detached	CCB	Community business
RH-1	One unit per lot	South of Market Mixed Use Districts	
RH-1 (S)	One unit per lot, secondary unit	SPD	South park
RH-2	Two units per lot	RED	Residential enclave
RH-3	Three units per lot	RSD	Residential/service
Residential, Mixed (Houses & Apartments)		SLR	Service/light industrial/residential
RM-1	Low density (1 unit per 800 sf)	SLI	Service/light industrial
RM-2	Moderate density(1 unit per 600 sf)	SSO	Service/secondary office
RM-3	Medium density (1 unit per 400 sf)	Eastern neighborhoods mixed use districts	
RM-4	High density (1 unit per 200 sf)	MUG	Mixed use, general
Residential-Commercial Combined Districts		MUO	Mixed use, office
RC-3	Medium density (1 unit per 400 sf)	MUR	Mixed use, residential
RC-4	High density (1 unit per 200 sf)	UMU	Urban mixed use
Downtown Residential Districts		Commercial Districts	
RH-DTR	Rincon Hill	C-2	Community business
SB-DTR	South Beach	C-3-S	Downtown support
TB-DTR	Transbay	C-3-R	Downtown retail
Neighborhood Commercial Districts		C-3-G	Downtown general
NC-1	Cluster (1 commercial story)	C-3-O	Downtown office
NC-2	Small-scale (2 commercial stories)	C-3-O(SD)	Downtown office (special)
NC-3	Moderate-scale (3+ commercial)	Industrial Districts	
NC-S	Shopping center (2 commercial)	C-M	Heavy commercial
NCD	Individual (Named, controls vary)	M-1	Light industrial
Neighborhood Commercial Transit Districts		M-2	Heavy industrial
NCT-1	Cluster	Mission Bay Districts	
NCT-2	Small scale	MB-OS	Open space
NCT-3	Moderate scale	MB-O	Office
NCT	Individual (Named, controls vary)		

4.2.2 Classifying Sample Parcels According to Zoning Code

As shown in Table 5, for residential zoning, there were 2,539 unimproved parcels in September 2010 (California State Public Data 2011). In this research, 30% (762 parcels) of the entire residential unimproved parcels were randomly selected. For mixed use and commercial zoning, the total number of unimproved parcels was 273. Fifty percent (137 parcels) of these parcels were randomly selected. Additionally, an acceptability standard to limit parcel selection to those parcels that were not less than minimum allowed parcel size according to the zoning code.

Table 5. Selected Sample Parcels of Residential and Mixed Districts

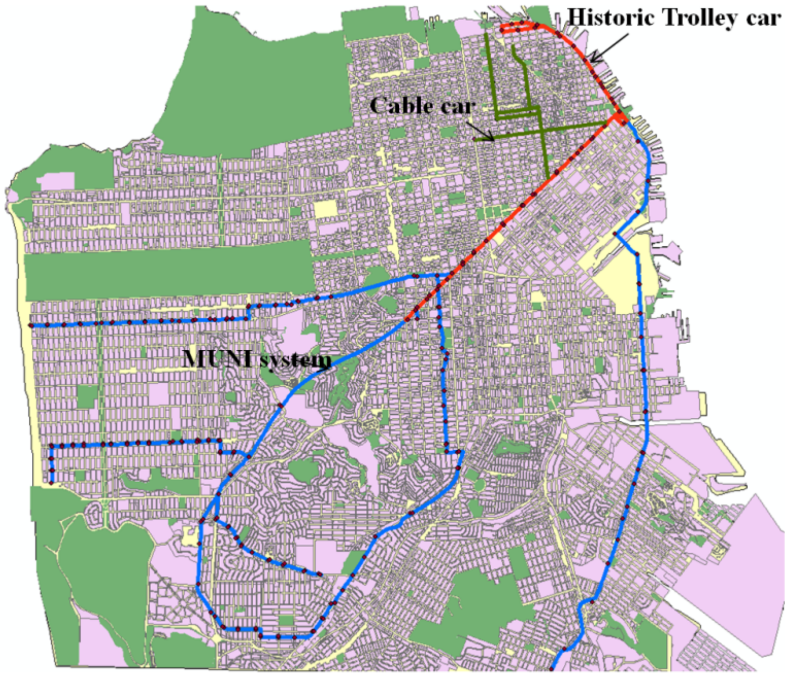
Zoning	Name of district	Minimum size	N
RH-1	Residential - House Districts, One Family	Width: 25ft, Area: 2,500sq	1,050
RH-1 (D)	Residential - House Districts, One Family - Detached	Width: 33ft, Area: 4,000sq	819
RH-1 (S)	Residential - House Districts, One Family - Secondary Unit	Width: 25ft, Area: 2,500sq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

4.2.3 Public Transit System Map

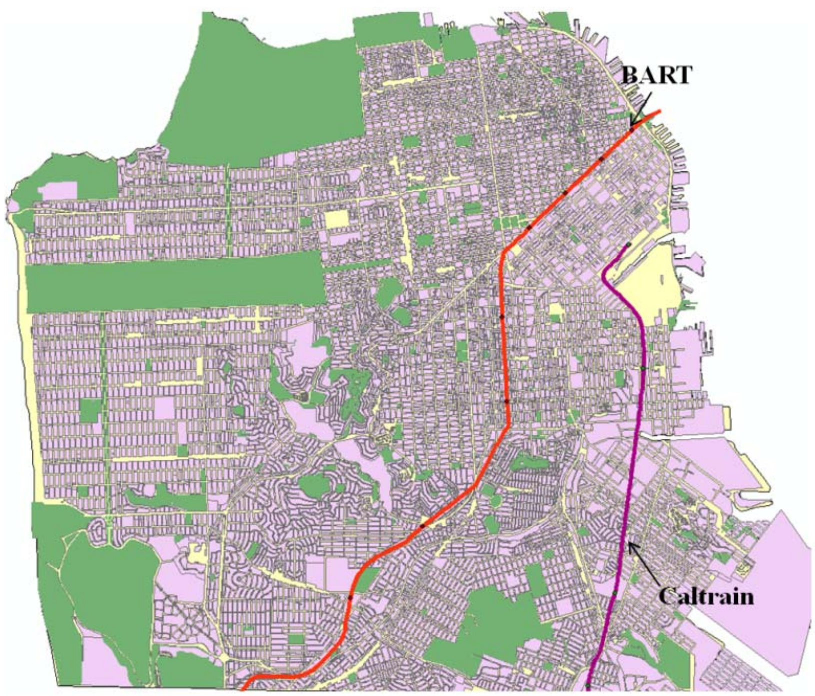
As shown in Figure 7, LEED map includes all relevant public transportation assets in the population map. This public transit data such as location, latitude, altitude, and routes were obtained from Metropolitan Transportation Commission (MTC 2011). Figure 7 (a) is all bus stops in 2010. These bus stops and routes include all three operators' bus stops such as SamTrans, GGT and AC Transit. Light rail system can be divided into three groups as shown in Figure 7 (b). This study scope includes all stations of MUNI light rail system, cable car and historic street car served by the San Francisco Municipal Railway (MUNI). When it comes to commuter rail system, BART and Caltrain rail system were included in this study as shown in Figure 7 (c).

(a)

Figure 7. Mapping for bus (a), light rail (b), and (c) commuter rail stations



(b)

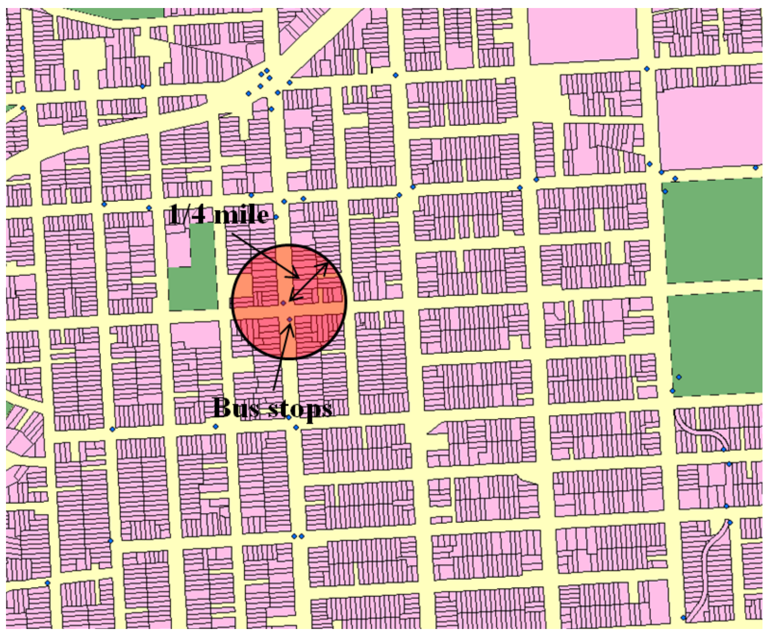


(c)

Figure 7. Continued

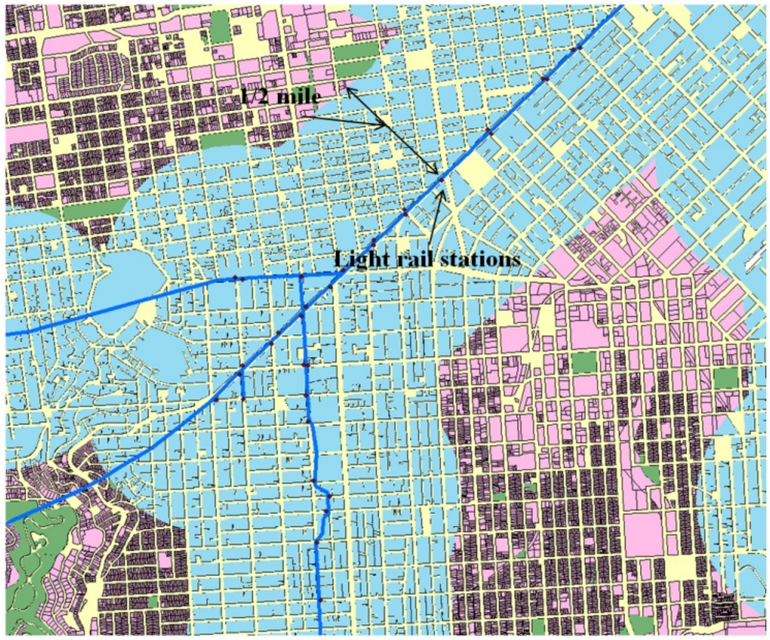
4.2.4 Randomly Selected Sample Parcels

In order to examine the impact of LEED-NC PTA qualified parcels for bus, light rail and commuter rail stations; first, the unimproved parcels within one-quarter mile of any bus stops were selected (See Figure 8 (a)). Second, LEED-NC PTA qualified parcels of light rail and commuter rail system, which is within half mile from stations, were selected as shown in Figure 8 (b) and (c), then the sample parcels were randomly selected for residential and mixed zones.

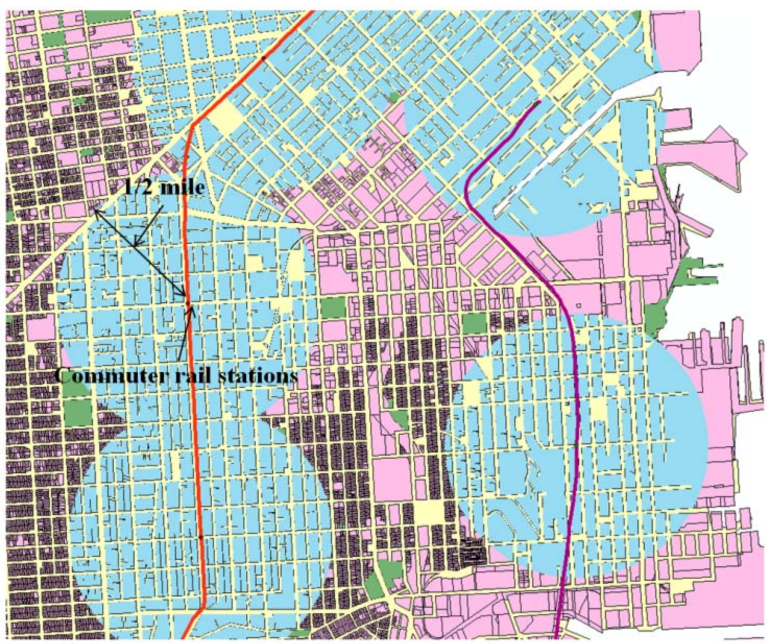


(a)

Figure 8. LEED-NC PTA parcels: bus (a), light rail (b) and commuter rail (c)



(b)

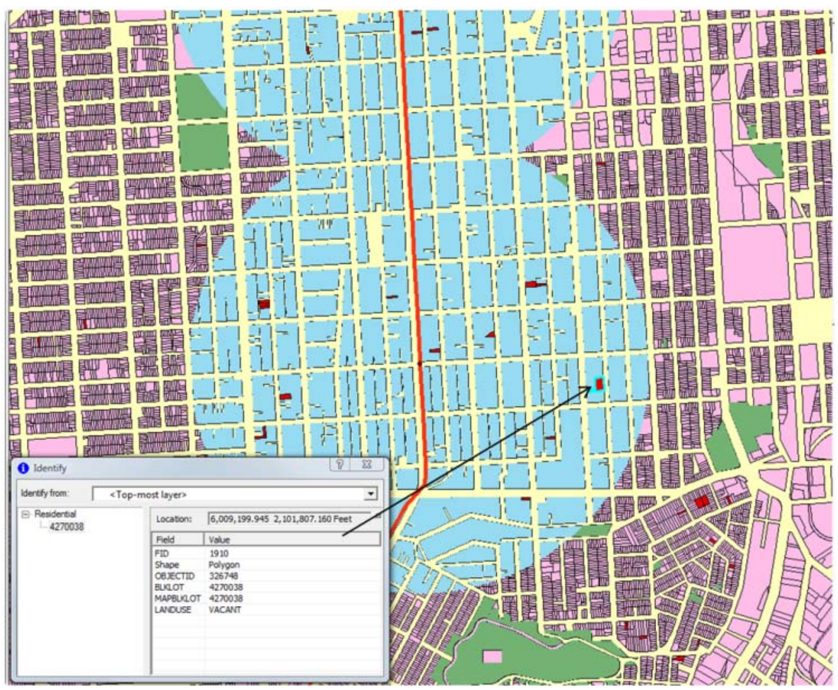


(c)

Figure 8. Continued

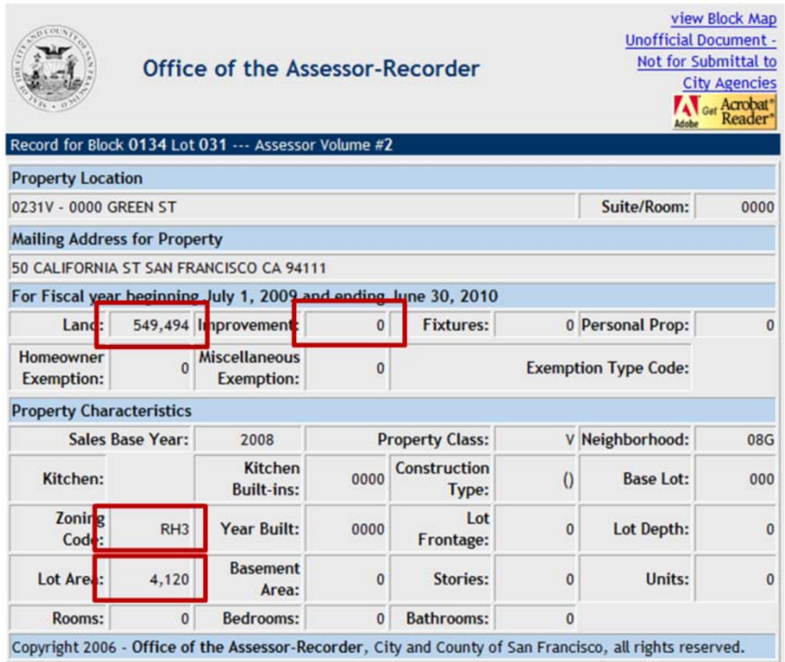
4.2.5 Collected Data of Sample Parcels

Figure 9 (a) represents randomly selected sample parcels in the LEED-NC PTA map. These selected parcels contain parcel identification information (i.e.: Block number of San Francisco County). The appraised land value, parcel size and zoning code of each parcel can be obtained by using the identification. After collecting selected parcels' identification, the appraised land value (in dollars), parcel size and zoning code were collected from the Office of the Assessor-Recorder from the City and County of San Francisco website as shown in Figure 9 (b). After collecting data, an excel matrix model was created by using GIS tools as shown in Table 6.



(a)

Figure 9. Parcel information (ID, land value, parcel size, and zoning code)



Office of the Assessor-Recorder

view Block Map
Unofficial Document - Not for Submittal to City Agencies
Get Acrobat Reader

Record for Block 0134 Lot 031 --- Assessor Volume #2

Property Location

0231V - 0000 GREEN ST		Suite/Room:	0000

Mailing Address for Property

50 CALIFORNIA ST SAN FRANCISCO CA 94111

For Fiscal year beginning July 1, 2009 and ending June 30, 2010

Land:	549,494	Improvement:	0	Fixtures:	0	Personal Prop:	0
Homeowner Exemption:	0	Miscellaneous Exemption:	0			Exemption Type Code:	

Property Characteristics

Sales Base Year:		2008		Property Class:	V	Neighborhood:	08G
Kitchen:		Kitchen Built-ins:	0000	Construction Type:	()	Base Lot:	000
Zoning Code:	RH3	Year Built:	0000	Lot Frontage:	0	Lot Depth:	0
Lot Area:	4,120	Basement Area:	0	Stories:	0	Units:	0
Rooms:	0	Bedrooms:	0	Bathrooms:	0		

Copyright 2006 - Office of the Assessor-Recorder, City and County of San Francisco, all rights reserved.

(b)

Figure 9. Continued

Table 6. Excel Matrix Model

Zoning	Parcel size (ft^2)	Land value ($)	$/ft^2	Number of bus stops	Closest distance from bus stop (mile)	Number of light rail stations	Closest distance from light rail station (mile)	Number of commuter rail stations	Closest distance from rail stations (mile)
RM-2	3,670	747,923	203.79	13	0.029667	3	0.178022	0	0.900423
RM-2	7,688	1,005,834	130.83	2	0.033597	3	0.162465	0	0.919433
RM-2	2,574	121,559	47.23	4	0.024706	2	0.106863	0	1.255389
RM-2	3,031	113,326	37.39	5	0.046277	2	0.349097	0	0.592487
RM-1	3,306	87,329	26.42	3	0.054804	3	0.261612	0	0.700413
RC-4	12,638	822,808	65.11	6	0.020972	2	0.060514	1	0.331779
RM-4	3,360	102,542	30.52	5	0.038657	2	0.095500	1	0.494905
RM-4	2,800	659,756	235.63	12	0.032773	3	0.100430	0	0.513361
RM-4	3,441	277,245	80.57	7	0.040398	2	0.065861	0	0.656270
RM-4	6,100	4,020,343	659.07	14	0.015161	3	0.015413	1	0.446389
RC-4	7,000	3,837,762	548.25	11	0.028130	3	0.175882	0	0.627979
RM-3	10,171	114,891	11.30	0	0.288772	0	0.541575	0	0.627736
RM-4	4,438	43,117	9.72	7	0.148155	0	0.536670	0	0.561182
RM-3	7,736	152,839	19.76	3	0.117947	0	0.519098	0	0.591641
RC-4	3,437	392,698	114.26	5	0.040806	3	0.321802	2	0.330753
RC-4	7,217	177,622	24.61	4	0.060197	3	0.334644	1	0.340066
RC-4	4,708	774,019	164.41	9	0.048821	2	0.382936	1	0.399051
RM-3	9,453	741,471	78.44	5	0.034828	0	0.729252	0	0.991047

5. DATA ANALYSIS AND INTERPRETATION

5.1 Mixed Zone

5.1.1 Descriptive Analysis

As shown in Table 7, the dependent variable, appraised unit value (\$/ft^2) of these unimproved parcels, had a mean value of approximately \$110.40 per square foot and standard deviation was \$140.02 per square foot. The mean of the number of bus stops within one-quarter mile of the centroid of the sample parcels was about 5.78 and had a standard deviation of 3.57. The mean value of number of light rail stations within half mile of the centroid of the sample parcels was 1.42. In addition, when it comes to the number of commuter rail stations within half of the centroid of the sample, the mean was 0.47 and the standard deviation was 0.71. Furthermore, the means of the nearest distance from the centroid of the sample parcels to bus stops, light rail, and commuter rail stations were respectively about 0.08, 0.40, and 0.96 miles. The average parcel size was about 5808.42 ft^2.

Table 7. Descriptive Statistics

	Mean	Std. deviation	N
UV_m	110.40	140.02	122
NB_m	5.78	3.58	122
NL_m	1.42	1.34	122
NR_m	0.47	0.71	122
DB_m	0.08	0.08	122
DL_m	0.40	0.29	122
DR_m	0.96	0.84	122
$AREA_m$	5,808.41	5,674.70	122

5.1.2 Scatter Plots

Scatter plot for UV_m versus NB_m indicated a positive relationship as shown in Figure 10. In other words, there is a positive relationship between appraised unit value of parcel and number of bus stops within one-quarter mile distance. The slope of this plot (0.682) indicates that as the number of bus stops increases, appraised unit value also increases. In addition, since p-value is less than 0.05 the relationship is significant.

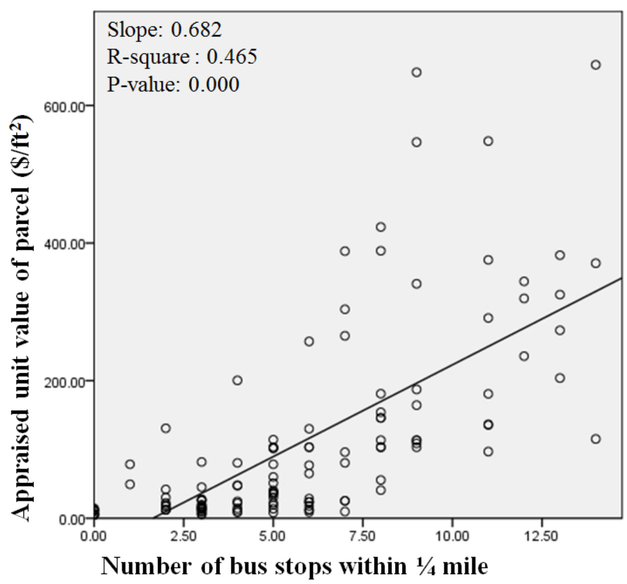


Figure 10. Scatter plot of UV_m versus NB_m

The slope of UV_m versus NL_m was 0.507 as shown in Figure 11 which indicates that there is a positive relationship between appraised unit value of parcel and number of light rail stations within one half mile distance which indicates that as the number of light rail stations increases, appraised unit value increases. In addition, since p-value is less than 0.05, it also shows a significant relationship between appraised unit value of parcel and number of light rail stations within one half mile distance.

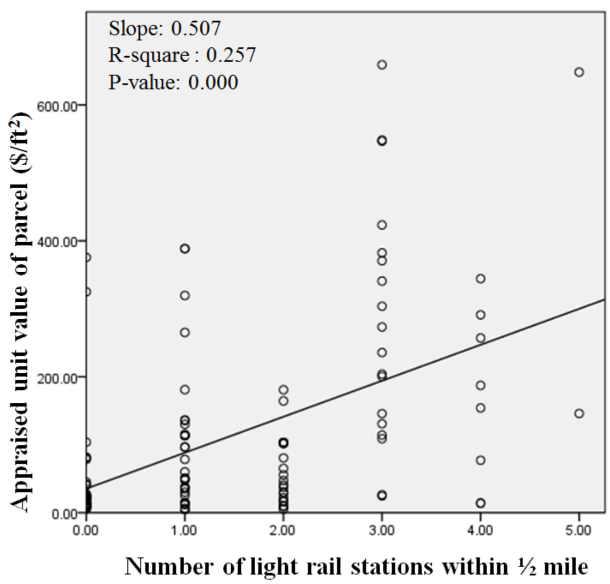


Figure 11. Scatter plot of UV_m versus NL_m

Figure 12 represents the relationship between UV_m and NR_m which shows a positive relationship between appraised unit value of parcel and number of commuter rail stations. The coefficient of 0.378 represents that as the number of commuter rail stations increases, appraised unit value also increases. Furthermore, since p-value is less than 0.05, it shows a significant relationship between them. However, with low R-square (0.143), the variability is explained by only 14.3%.

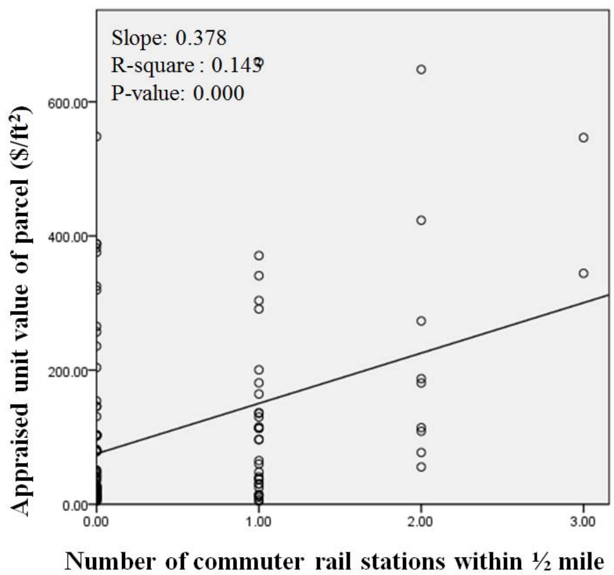


Figure 12. Scatter plot of UV_m versus NR_m

The scatter plot for UV_m and DB_m shows a negative relationship between appraised unit value and distance from parcel centroid to nearest bus stop as shown in Figure 13. In other words, the coefficient of -0.459 represents that appraised unit value of a parcel decreases as the distance to the nearest bus stop increase. Since p-value is less than 0.05, it proves that there is a significant relationship between them.

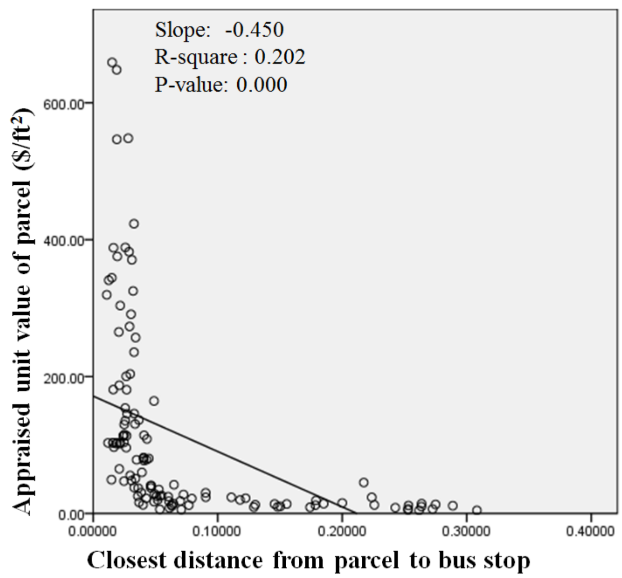


Figure 13. Scatter plot of UV_m versus DB_m

Figure 14 represent the relationship between UV_m and DL_m which shows a negative relationship between appraised unit value of parcel and closest distance from parcel to light rail station. This means that, as the appraised unit value of parcel increases, closest distance from parcel to light rail station decreases since the coefficient is -0.371. It also proves that there is a significant relationship since p-value is less than 0.05.

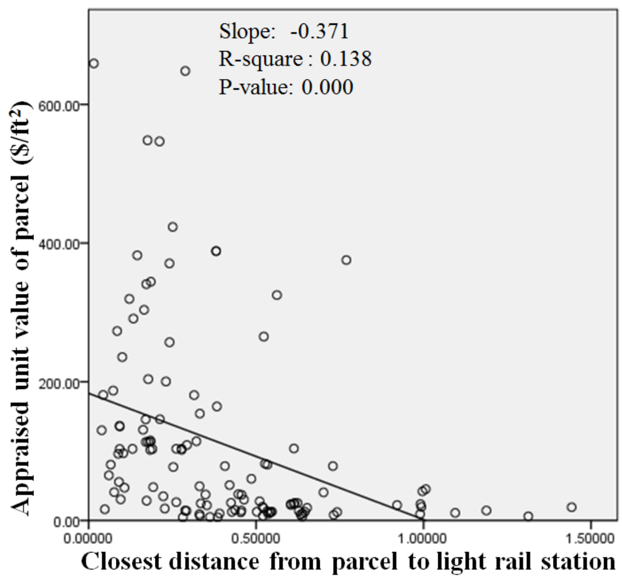


Figure 14. Scatter plot of UV_m versus DL_m

The scatter plot of UV_m and DR_m proves that there is no relationship between appraised unit value of parcel and closest distance from parcel centroid to commuter rail stations because p-value is higher than 0.05. For mixed zone, closest distance from parcel to commuter rail station is not related to appraised unit value of parcel as shown in Figure 15.

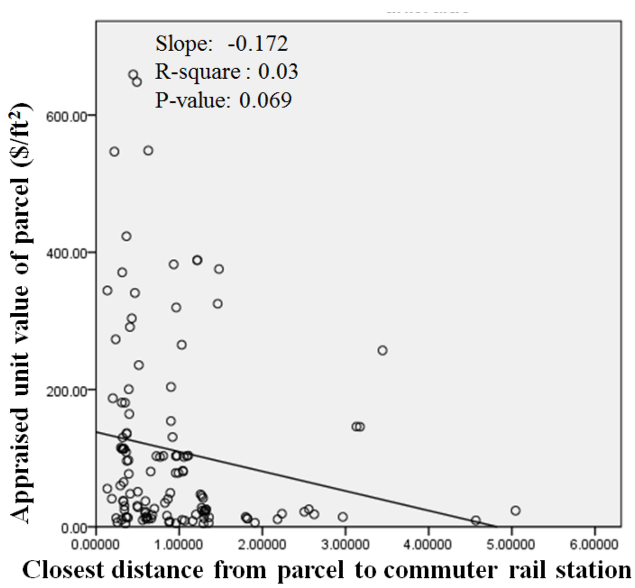


Figure 15. Scatter plot of UV_m versus DR_m

5.1.3 Correlation Analysis

Table 8. Pearson's Correlation Results

	UV_m	**NB_m**	**NL_m**	**DB_m**	**NR_m**	**DL_m**	**DR_m**	**$AREA_m$**
Correlation								
UV_m	1	0.682	0.507	-0.450	0.378	-0.371	-0.172	-0.092
NB_m	0.682	1	0.379	-0.607	0.352	-0.433	-0.209	-0.128
NL_m	0.507	0.379	1	-0.331	0.455	-0.651	-0.206	-0.027
DB_m	-0.450	-0.607	-0.331	1	-0.223	0.411	0.210	0.140
NR_m	0.378	0.352	0.455	-0.223	1	-0.390	-0.509	-0.177
DL_m	-0.371	-0.433	-0.651	0.411	-0.390	1	0.495	0.029
DR_m	-0.172	-0.209	-0.206	0.210	-0.509	0.495	1	0.164
$AREA_m$	-0.092	-0.128	-0.027	0.140	-0.177	0.029	0.164	1
Sig (1-tailed)								
UV_m		0.000	0.000	0.000	0.000	0.000	0.069	0.047
NB_m	0.000		0.000	0.000	0.000	0.000	0.010	0.080
NL_m	0.000	0.000		0.000	0.000	0.000	0.011	0.383
DB_m	0.000	0.000	0.000		0.007	0.000	0.010	0.062
NR_m	0.000	0.000	0.000	0.007		0.000	0.000	0.025
DL_m	0.000	0.000	0.000	0.000	0.000		0.000	0.376
DR_m	0.069	0.010	0.011	0.010	0.000	0.000		0.035
$AREA_m$	0.047	0.070	0.383	0.062	0.025	0.376	0.035	

Table 8 represents the Pearson's correlation results which show that only DR_m is not significantly correlated to UV_m. In detail, NB_m, NL_m, and NR_m show a positive correlation to the dependent variable, UV_m. However, DB_m, and DL_m, represent a negative correlation with UV_m. Therefore, the impact of independent variables on UV_m indicates that appraised unit value of parcel increases as the number of LEED qualified transit stops increases (bus, light rail, and commuter rail). In addition, appraised unit value of parcel increases as the distance to LEED qualified bus stops and light rail stations from parcel centroid decrease.

When it comes to the correlation between independent variables, there is a positive relationship between NB_m, NL_m, and NR_m which means that the number of bus stops within one-quarter mile distance increases as the number of light rail or commuter rail stations increases within a half mile distance. Furthermore, DB_m, DL_m, and DR_m have a positive relationship. In other words, when the distance from parcel centroid to bus stop is shorter, the distance from parcel centroid to light rail and commuter rail stations is also shorter.

When it comes to parcel size, NB_m, NL_m, and NR_m are negatively related to $AREA_m$ which means that the number of bus stops, light rail and commuter rail stations decreases as parcel size increases. However, DB_m, DL_m, and DR_m are positively related to $AREA_m$ which indicates that as parcel size increases, the distance from parcel centroid to transit stops also increases.

5.1.4 Original Regression Analysis and Check for Normality

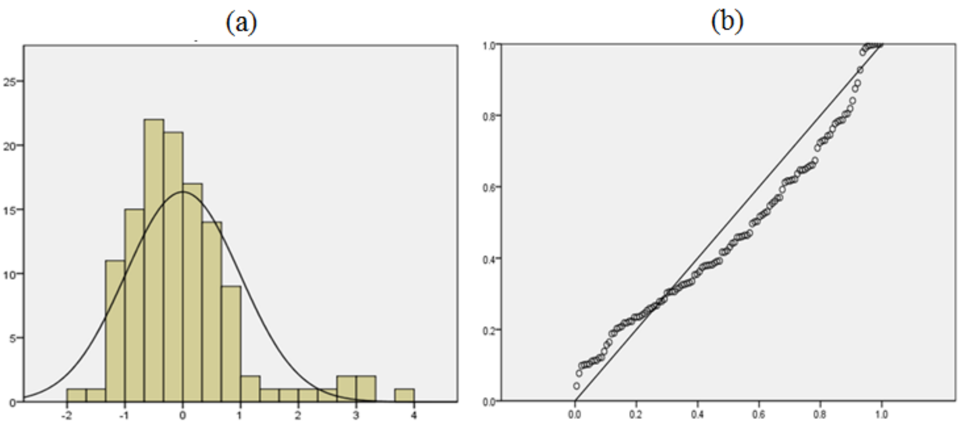
Table 9. Coefficients of Original Model for Mixed Zone

Variable	*β*	Std. Error	*t-value*	*p-value*	VIF
(Constant)	-96.481	39.115	-2.467	0.015	
NB_m	22.232	3.299	6.740	0.000	1.797
NL_m	33.569	9.588	3.710	0.000	2.133
DB_m	-62.416	146.533	-0.426	0.671	1.679
NR_m	12.975	16.512	0.786	0.434	1.755
DL_m	-70.239	48.924	1.436	0.154	2.517
DR_m	-2.283	14.026	-0.163	0.871	1.795
$AREA_m$	-0.0007	0.0002	0.472	0.002	1.069

Dependent variable: UV_m

The multiple linear regression analysis with original dependent variable yields a model adjusted R-square value of 0.692. Also, p-value is less than 0.05 in the ANOVA test which proves that the model is significant as shown in Table 9. Before proceeding to the interpretation, it is essential to check if the residuals are normally distributed.

Kolmogorov-Smirnov value is used to check for the normality of residuals as shown in Figure 16 (c). The p-value of the test is less than 0.05, which proves that residuals are not normally distributed. In addition, Q-Q plot and histogram of standardized residuals confirm that the original model is not normally distributed in Figure 16 (a) and (b). Therefore, transformation of the dependent variable is necessary.



	Kolmogorov-Smirnov			Shapiro-Wilk		
	Statistic	df	*p-value*	Statistic	df	*p-value*
Standardized residual	0.116	122	0.000	0.881	122	0.000

(C)

Figure 16. Normality check for residuals of original model for mixed zone

5.1.5 Transformation of Dependent Variable

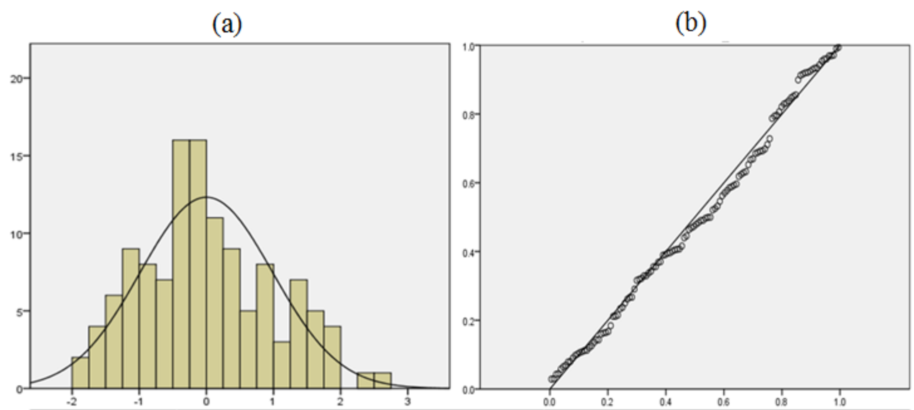
The dependent variable, UV_m was transformed since the original multiple linear regression model residuals were not normally distributed. To obtain an appropriate transformed value, Box-Cox analysis was used as shown in Figure 17. As a result of the analysis, the transformation for the dependent variable is as follows:

$$\text{Transformed } UV_m = (\text{Original } UV_m)^{0.1}$$

	lambda	rmse
25	-.60	45.97
26	-.50	41.83
27	-.40	38.71
28	-.30	36.48
29	-.20	35.08
30	-.10	34.45
31	.10	34.37
32	.20	37.15
33	.30	39.68
34	.40	43.14
35	.50	47.65
36	.60	53.38
37	.70	60.54
38	.80	69.40
39	.90	80.28
40	1.00	93.62
41	1.10	109.95

Figure 17. Transformation value suggested by Box-Cox analysis

After transformation of the dependent variable, the Kolmogorov-Smirnov value confirmed that the residuals of the transformed model are normally distributed since the p-value is higher than 0.05 as shown in Figure 18 (c). Furthermore, the Q-Q plot and histogram of standardized residuals also prove that the transformed model is normally distributed in Figure 18 (a) and (b).



	Kolmogorov-Smirnov			Shapiro-Wilk		
	Statistic	df	*p-value*	Statistic	df	*p-value*
Standardized residual	0.058	122	0.200	0.982	122	0.102

(C)

Figure 18. Check for normality of transformed model for mixed zone

5.1.6 Multiple Linear Regression Analysis

In this study, the backward elimination method for multiple linear regression analysis was used to select independent variables for the transformed dependent variable, appraised unit value. In the original model, only three independent variables are significant predictors while only DR_m was removed in the backward elimination method after transformation of the dependent variable.

Table 10. ANOVA Test Results and Adjusted R-square

Model	Sum of Squares	Df	Mean Square	*f-value*	*p-value*	Adjusted R-square
Regression	3.388	7	0.484	42.388	0.000	0.713
Residual	1.302	114	0.011			
Total	4.690	121				

a. Predictors: (Constant), NB_m, NL_m, DB_m, NR_m, DL_m, $AREA_m$

The p-value in the ANOVA test is less than 0.05 as shown in Table 10. The null hypothesis, there was no linear relationship between dependent and independent variables, was rejected. Therefore, the statistical model is significant to predict the dependent variable, the transformed UV_m. In addition, the adjusted R-square for this model was 0.713, which means that 71.3% variability in the transformed UV_m was explained by the independent variables (i.e.: NB_m, NL_m, DB_m, NR_m, DL_m, and $AREA_m$). However, 28.7% of the variability was explained by some unknown factors not considered in this study.

Table 11. Coefficients of Transformed Model for Mixed Zone

Variable	B	Std. Error	*t-value*	*p-value*	VIF
(Constant)	1.339	0.035	38.018	<0.05	1.797
NB_m	0.027	0.004	7.454	<0.05	1.679
NL_m	0.036	0.009	4.189	<0.05	2.133
NR_m	0.013	0.018	7.364	<0.05	2.517
DB_m	-0.751	0.160	-4.702	<0.05	1.755
DL_m	-0.007	0.015	6.231	<0.05	1.795
$AREA_m$	-0.0008	0.0001	-5.342	<0.05	1.069

Table 11 shows the coefficients of the predictive model for the mixed zone. The DR_m variable was excluded in the predictive model since p-value was higher than 0.05 while the other six independent variables were significant predictors for the transformed appraised unit value. In addition, there was no multi-collinearity problem in the predictive model since the Variance Inflation Factor (VIF) ranged from 1.06 to 2.5.

Equation (2) based on the coefficient analyzed in this study was developed to analyze how the unit value of the parcels can be affected by LEED-NC PTA and parcel size. The multiple linear regression model can explain 71.3% variability of the transformed UV_m. Therefore, it is necessary to mathematically solve the transformed equation (3) using the transformed dependent variable to the original un-transformed dependent variable such that it can predict UV_m as described in equation (3).

$$UV_m^{0.1} = 1.339 + 0.027 \cdot NB_m + 0.036 \cdot NL_m + 0.013 \cdot NR_m - 0.751 \cdot DB_m - 0.007 \cdot DL_m - 0.0008 \cdot AREA_m \quad (2)$$

$$UV_m = [1.339 + 0.027 \cdot NB_m + 0.036 \cdot NL_m + 0.013 \cdot NR_m - 0.751 \cdot DB_m - 0.007 \cdot DL_m - 0.0008 \cdot AREA_m]^{(1/0.1)} \quad (3)$$

The estimated coefficients analyzed in the regression analysis are as follows:

- β_1 is 0.027 which means that one additional bus stop within one-quarter mile distance causes a \$0.027/ ft^2 increase in the transformed appraised unit value of parcel.
- β_2 is 0.036 which means that one additional light rail station within half mile distance causes a \$0.036/ ft^2 increase in the transformed appraised unit value of parcel.
- β_3 is 0.013 which means that one additional commuter rail station within half mile distance causes a \$0.013/ ft^2 increase in the transformed appraised unit value of parcel
- β_4 is -0.751 which means that as the closest distance from the parcel centroid to bus stop increases by one mile, appraised unit value of parcel decreases by \$0.751/ft^2.
- β_5 is -0.007 which means that as the closest distance from the parcel centroid to light rail stations increases by one mile, appraised unit value of parcel decreases by \$0.007/ ft^2.
- β_6 is -0.0008 which means that one additional sf^2 of parcel size causes an \$0.0008/ ft^2 decrease in transformed appraised unit value of parcel

5.2 Residential Zone

5.2.1 Descriptive Analysis

Table 12 represents the descriptive statistics of all variables for mixed zone. The mean of the dependent variable, UV_r, had $44.21 per square foot and standard deviation of $56.91 per square foot. Within one-quarter mile of the centroid of the sample parcels, the mean of the number of bus stops was 4.20 and standard deviation was 2.78. The number of light rail stations within half mile of the centroid of the sample parcels had approximately 1.1 mean values while the mean of the number of commuter rail stations was 0.32 with standard deviation of 0.47. In addition, the mean of the nearest distance from the centroid of the sample parcels to bus stops was approximately 0.09 miles. Furthermore, the nearest distance from the centroid of the sample parcels to light rail and commuter rail stations was 0.43, 1.01 miles respectively. The average parcel size was 7,049.50 ft^2.

Table 12. Descriptive Statistics

	Mean	Std. deviation	N
UV_r	44.21	56.91	308
NB_r	4.20	2.78	308
NL_r	1.1	0.99	308
NR_r	0.32	0.47	308
DB_r	0.09	0.08	308
DL_r	0.43	0.32	308
DR_r	1.01	0.82	308
$AREA_r$	7,049.50	5,674.70	308

5.2.2 Scatter Plots

Figure 19 represent the scatter plot for UV_r versus NB_r. The plot indicates that there is a positive relationship between appraised unit value of parcel and number of LEED-PTA qualified bus stops for residential zone. In detail, one additional bus stop within one-quarter mile distance from parcel centroid is related to about $0.706/ft^2 increase in appraised unit value of parcels. In addition, since p-value is less than 0.05, the relationship is significant.

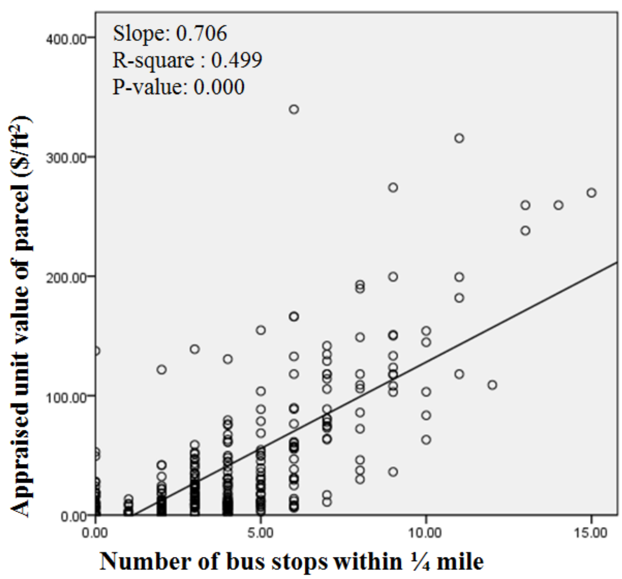


Figure 19. Scatter plot of UV_r versus NB_r

When it comes to the scatter plot for UV_r versus NL_r, the slope was 0.612 as shown in Figure 20. It indicates that there is a positive relationship between appraised unit value of parcel and number of light rail stations within one half mile distance. In other words, one additional light rail station within half mile distance is related to $\$0.612/ft^2$ growth of appraised unit value of parcel. In addition, it shows that there is significant relationship since p-value is less than 0.05.

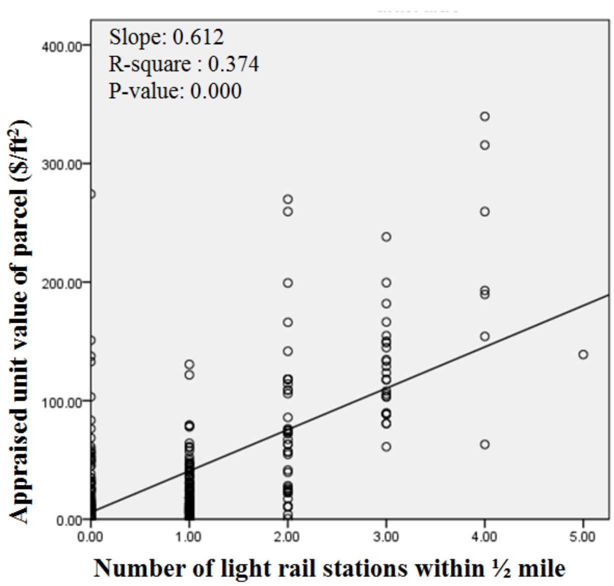


Figure 20. Scatter plot of UV_r versus NL_r

Figure 21 represents the relationship between UV_r and NR_r. The p-value (0.077) proves that there is no significant relationship between appraised unit value of parcel and number of commuter rail stations. In detail, in the residential zone, appraised unit value of parcel is not related to the number of commuter rail station within one half mile distance from parcel centroid.

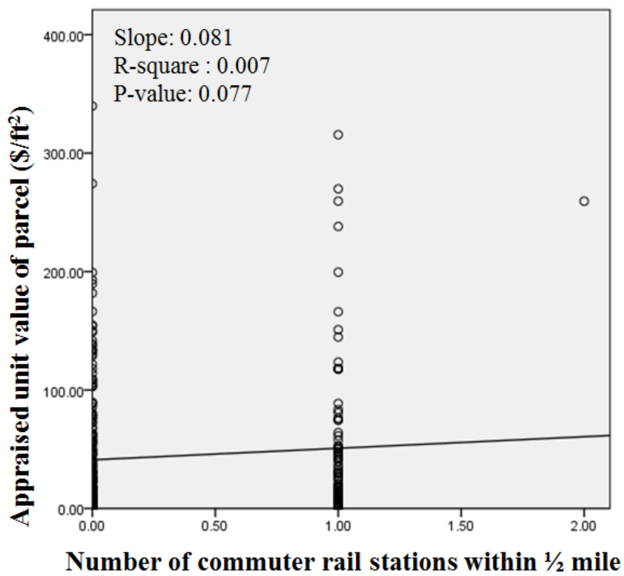


Figure 21. Scatter plot of UV_r versus NR_r

Scatter plot for UV_r and DB_r represents a negative relationship which means that there is a negative relationship between appraised unit value of parcel and closest distance from parcel to bus stop as shown in Figure 22. In detail, 1 mile increase in the distance to the nearest bus stop is related to a $0.34/ft^2 decrease of appraised unit value of the parcel in residential zone. In addition, the relationship is significant since p-value is less than 0.05.

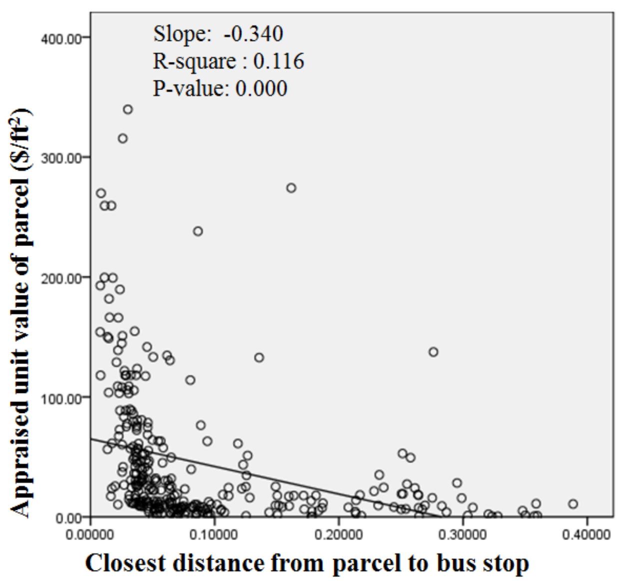


Figure 22. Scatter plot of UV_r versus DB_r

As shown in Figure 23, the scatter plot of UV_r and DL_r indicates that there is no relationship between appraised unit value of parcel and closest distance from parcel centroid to light rail station since p-value is 0.059. Therefore, for residential zone, appraised unit value of parcel is not related to closest distance from parcel centroid to light rail station.

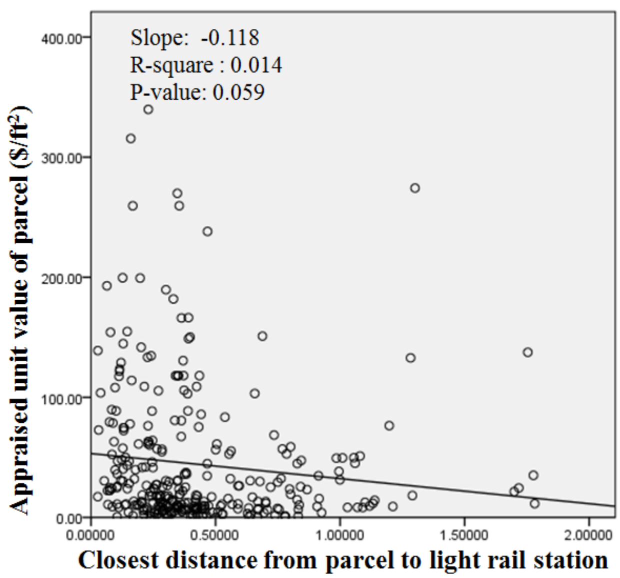


Figure 23. Scatter plot of UV_r versus DL_r

Figure 24 represents that there is no relationship between UV_r and DR_r since p-value is 0.085. Therefore, it indicates that there is no relationship between appraised unit value of parcel and closest distance from parcel centroid to commuter rail station for residential zone.

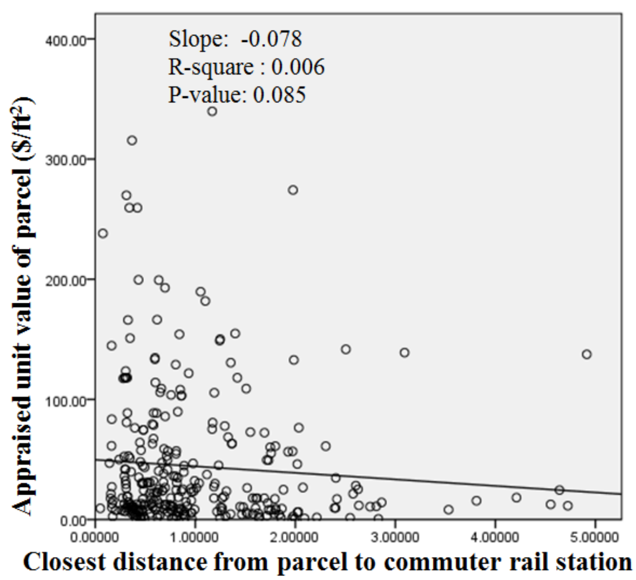


Figure 24. Scatter plot of UV_r versus DR_r

5.2.3 Correlation Analysis

Table 13. Pearson's Correlation Results

	UV_r	NB_r	NL_r	DB_r	DL_r	NR_r	DR_r	$AREA_r$
Correlation								
UV_r	1	0.706	0.612	-0.340	-0.118	0.081	-0.078	-0.042
NB_r	0.706	1	0.473	-0.616	0.352	-0.163	-0.194	-0.011
NL_r	0.612	0.473	1	-0.282	-0.617	0.028	-0.122	-0.036
DB_r	-0.340	-0.616	-0.282	1	0.272	-0.118	0.374	0.041
DL_r	-0.118	-0.163	-0.617	0.272	1	-0.145	0.394	0.011
NR_r	0.081	0.072	0.028	-0.118	-0.145	1	-0.548	-0.005
DR_r	-0.078	-0.194	-0.122	0.374	0.394	-0.548	1	-0.012
$AREA_r$	-0.042	-0.011	-0.036	0.041	0.011	-0.005	-0.012	1
Sig (1-tailed)								
UV_r		0.000	0.000	0.000	0.019	0.077	0.085	0.037
NB_r	0.000		0.000	0.000	0.002	0.105	0.000	0.023
NL_r	0.000	0.000		0.000	0.000	0.314	0.016	0.064
DB_r	0.000	0.000	0.000		0.000	0.019	0.000	0.037
DL_r	0.019	0.002	0.000	0.000		0.005	0.000	0.024
NR_r	0.077	0.105	0.314	0.019	0.005		0.000	0.068
DR_r	0.085	0.000	0.016	0.000	0.000	0.000		0.016
$AREA_r$	0.037	0.023	0.064	0.037	0.024	0.068	0.016	

As shown in Table 13, for mixed zone, five independent variables (NB_r, NL_r, DB_r, DL_r, and $AREA_r$) are correlated to UV_r at $p<=0.05$. In addition, NB_r, and NL_r has a positive relationship to the UV_r while DB_r, DL_r and $AREA_r$ have a negative relationship. In detail, first, the appraised unit value of parcel increases as the number of LEED qualified bus and light rail stations increases. Second, as the distance to LEED qualified bus stops and light rail station from parcel centroid decreases, appraised unit value of parcel increases.

The correlation between independent variables, NB_r and NL_r is a positive relationship, which means that as the number of bus stops within one-quarter mile distance from parcel centroid increases, the number of light rail station within a half mile distance also increases. In addition, DB_r, DL_r, and DR_r have a positive relationship which means that when the distance from parcel centroid to bus stop is shorter, the distance from parcel centroid to light rail and commuter rail stations is also shorter.

NB_r is negatively related to $AREA_r$. In detail, the number of bus stops decreases as the parcel size increases. However, DB_r, DL_r, and DR_r are positively related to $AREA_r$. It indicates that as the distance from parcel centroid to transit stops (bus, light rail, and commuter rail) increases, the parcel size increases.

5.2.4 Original Regression Analysis and Check for Normality

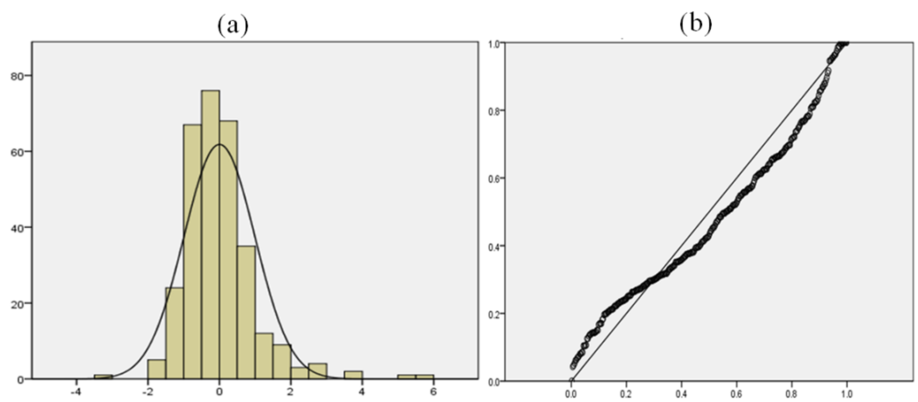
Table 14. Coefficients of Original Model for Mixed Zone

Variable	*β*	Std. Error	*t-value*	*p-value*	VIF
(Constant)	-66.728	7.295	-9.147	0.000	
NB_r	10.682	0.999	10.693	0.000	2.151
NL_r	33.025	2.888	11.435	0.000	2.319
DB_r	50.477	30.902	1.633	0.103	1.890
DL_r	57.000	8.671	6.574	0.000	2.180
NR_r	8.503	4.817	1.765	0.079	1.459
DR_r	-1.608	3.207	-0.502	0.616	1.934
$AREA_r$	-0.00006	0.000	-0.814	0.017	1.011

Dependent variable: UV_r

As shown in Table 14, the four variables (NB_r, NL_r, DL_r and $AREA_r$) are significant predictors of UV_r. The original model has adjusted R-square value of 0.611. In addition, in the ANOVA test to determine if the model is significant or not, p-value is less than 0.05. Therefore, it indicated that the model is significant. However, before proceeding for the interpretation, it needs to be checked for normality of residuals.

The Kolmogorov-Smirnov value proved that the residual is not normally distributed as shown in Figure 25 (c). In addition, in Figure 25 (a) and (b), Q-Q plot and histogram of standardized residuals confirmed that the original model is not normally distributed. Therefore, for residential zone, the transformation of dependent variable is necessary.



	Kolmogorov-Smirnov			Shapiro-Wilk		
	Statistic	df	*p-value*	Statistic	df	*p-value*
Standardized residual	0.096	308	0.000	0.885	308	0.000

(C)

Figure 25. Normality check for residuals of original model for residential zone

5.2.5 Transformation of Dependent Variable

Since residuals were not normally distributed, UV_r was transformed by using Box-Cox analysis as shown in Figure 26. The appropriate transformation value was 0.3. The transformed UV_r is as follows:

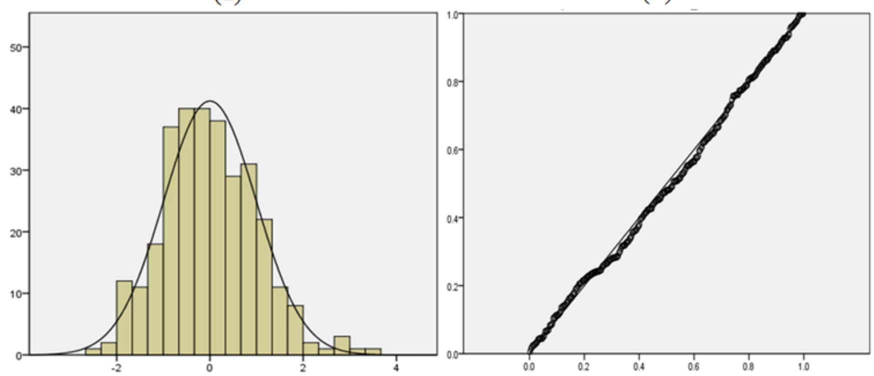
$$\text{Transformed } UV_r = (\text{Original } UV_r)^{0.3}$$

	lambda	rmse
25	-.60	47.38
26	-.50	38.47
27	-.40	31.90
28	-.30	27.08
29	-.20	23.58
30	-.10	21.08
31	1.53E-015	19.37
32	.10	18.30
33	.20	17.75
34	.30	17.69
35	.40	18.08
36	.50	18.93
37	.60	20.29
38	.70	22.23
39	.80	24.86
40	.90	28.31

Figure 26. Transformation value suggested by Box-Cox analysis

After transformation of dependent variable, the Kolmogorov-Smirnov value proved that the residuals are normally distributed since p-value is higher than 0.05. In addition, Q-Q plot and histogram of standardized residuals confirmed that the residuals have a normal distribution as shown in Figure 27.

(a) (b)



	Kolmogorov-Smirnov			Shapiro-Wilk		
	Statistic	df	*p-value*	Statistic	df	*p-value*
Standardized residual	0.038	308	0.200	0.992	308	0.098

(C)

Figure 27. Check for normality for transformed model for residential zone

5.2.6 Multiple Linear Regression Analysis

In the transformed model, three independent variables were excluded by using the backward elimination method. NB_r, NL_r, DB_r, and $AREA_r$ were significant predictors.

Table 15. ANOVA Test Results and adjusted R-square

Model	Sum of Squares	df	Mean Square	*f-value*	*p-value*	Adjusted R-square
Regression	211.631	7	30.233	70.435	0.000	0.622
Residual	128.770	300	0.429			
Total	340.401	307				

a. Prdictors: (Constant), NB_r, NL_r, DB_r, $AREA_r$

Table 15 represents the ANOVA test results and adjusted R-square. Since p-value was less than 0.05, it proved the transformed model was significant. In addition, the adjusted R-square was 0.622 which means that 62.2% variability was explained by the transformed model. However, 37.8% of the variability was explained by unknown factors not considered in the transformed model.

Table 16. Coefficients of Transformed Model for Residential Zone

Variable	β	Std. Error	*t-value*	*p-value*	VIF
(Constant)	1.043	0.144	7.238	<0.05	2.151
NB_r	0.170	0.020	8.629	<0.05	2.319
NL_r	0.546	0.057	9.572	<0.05	1.890
DB_r	-0.154	0.610	-5.747	<0.05	2.180
$AREA_r$	-0.0006	0.00007	-6.702	<0.05	1.934

The coefficients of NB_r, NL_r, DB_r, and $AREA_r$ were 1.170, 0.546, -1.154 and -0.0006 respectively as shown in Table 16. In addition, there was no multi-colinearity problem since the VIF range was from 1.890 to 2.319.

The multiple linear regression model for transformed dependent variable was established as shown in Equation (4). Since the Equation (4) was used the transformed dependent variable, it needed to be retransformed as shown in Equation (5).

$$UV_r^{0.3} = 1.043 + 0.170 \cdot NB_r + 0.546 \cdot NL_r - 0.154 \cdot DB_r - 0.0006 \cdot AREA_r \quad (4)$$

$$UV_r = [1.043 + 0.170 \cdot NB_r + 0.546 \cdot NL_r - 0.154 \cdot DB_r - 0.0006 \cdot AREA_r]^{(1/0.3)} \quad (5)$$

The estimated coefficients analyzed in the regression analysis are as follows:

- β_1 is 0.170 which means that one additional bus stop within one-quarter mile distance in a residential zone is related to $0.17/ft^2 increases of transformed appraised unit value of a parcel.
- β_2 is 0.546 which means that one additional light rail station within half mile distance is related to $0.546/ft^2 increases of transformed appraised unit value of parcel.
- β_3 is -0.154 which means that as the distance from the parcel to closest bus stop decreases by one mile, appraised unit value of parcel increases by $0.154/ft^2.
- β_4 is -0.0006 which means that one additional sf^2 of the parcel size is related to $0.0006/ft^2 decrease of transformed appraised unit value of parcel

5.3 Comparison between Mixed and Residential Zone

5.3.1 Diagnostics for Normality of Residuals and Transformation

In this study, multiple linear regression analysis with one-way ANOVA test was performed to determine the impact of LEED-PTA on appraised unit value of parcel. This analysis was conducted respectively in mixed and residential zone to establish predictive model for appraised unit value of parcel. After transformation of dependent variable by using Box-Cox analysis to establish the best goodness of fit models, the residuals of two models were normally distributed and the p-value is less than 0.05 in the ANOVA table respectively. In addition, The Q-Q plot and scatter plot of standardized residuals indicated that there was no heteroscedasticity problem and confirmed robustness of data. Therefore, the value proved that the predictive models were significant in testing hypothesis. The following transformation was used for dependent variable:

$$\text{Transformed } UV_m = (\text{Original } UV_m)^{0.1}$$

$$\text{Transformed } UV_r = (\text{Original } UV_r)^{0.3}$$

5.3.2 Transformed Model and Its Validity

Backward elimination method of multiple linear regression analysis was used to select independent variables for the transformed models. For the predictive model of mixed zone, six independent variables were significant predictors for the transformed model. In addition, there was no multi-collinearity problem of the predictive model since the Variance Inflation Factor (VIF) was ranged from 1.06 to 2.5. Furthermore, the adjusted R-square of the transformed model was 0.713, which indicates that 71.3% variability in transformed appraised unit value of parcel could be explained by these variables. Figure 28 represents actual appraised unit value of parcel by comparing with predicted appraised unit value of parcel for mixed zone.

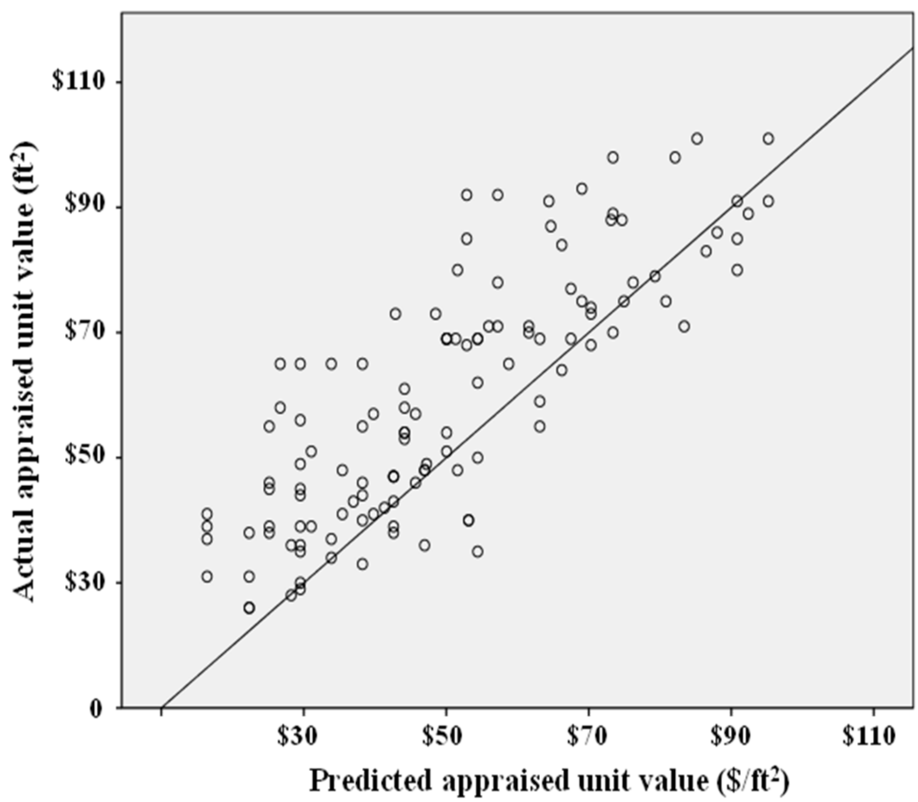


Figure 28. Actual versus predicted appraised unit value for mixed zone

When it comes to the predictive model for residential zone, an adjusted R-square for the model was 0.622 thus the independent variables together accounted for 62.2% variability in the transformed appraised unit value of parcel as shown in Figure 29. Furthermore, there is no multi-collinearity problem since VIF is less than 10. Figure 29 visually shows actual appraised unit value of parcel and predicted appraised unit value of parcel.

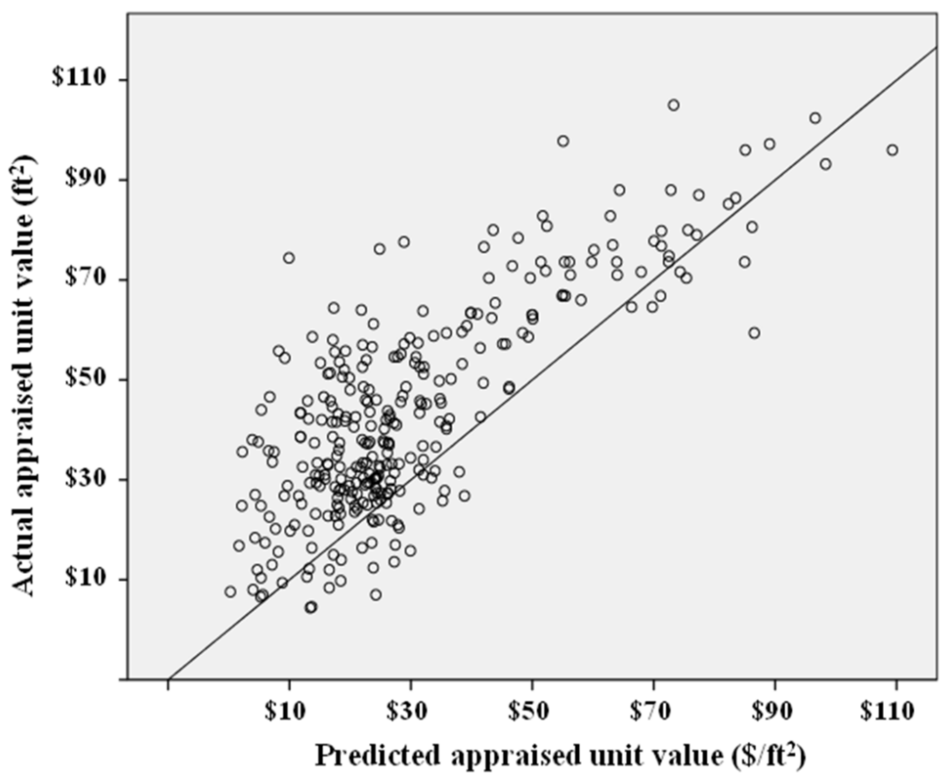


Figure 29. Actual versus predicted appraised unit value for residential zone

6. CONCLUSIONS

As needs grow for environmental certification systems, LEED-NC is being widely adopted in the U.S to evaluate environmental performance of buildings. However, LEED-NC projects require higher planning and monitoring than typical buildings. In response, in order to investigate the economic impact of LEED rating systems, Park conducted a study to identify the impact of LEED criteria on appraised unit value of parcels in Houston (Park 2009). In addition, Joshi focused on the relationship between LEED PTA criteria and appraised unit value of parcels (Joshi 2009). However, commuter rail systems, one of LEED PTA criteria, were not included in the studies since Houston does not have commuter rail systems.

In this study, as an extension of the studies of Park and Joshi, the objective is to further investigate the impact of LEED-NC PTA criteria on appraised unit value of parcels. As a population of interest, San Francisco County was chosen since it is known as a region having well-organized transportation systems including bus, light rail and commuter rail systems.

If this study establishes that LEED-NC PTA criteria affect appraised unit value of parcels, this could affect land development strategies. In addition, if the results of the San Francisco County study are similar to the Houston studies, outcomes of both studies (Joshi 2009, Park 2009) would be strengthened.

6.1 Results and Interpretation

6.1.1 Correlation Results for Mixed and Residential Zones

Pearson's correlation analysis performed to examine the relationships between dependent variable (appraised unit value of parcel) and independent variables. First is the correlation between appraised unit value of parcel and number of bus stops within one-quarter mile distance. In mixed and residential zones, it represents a positive relationship respectively since p-value is less than 0.05. Residential zone has stronger positive relationship than mixed zone. In addition, in terms of the correlation between appraised unit value of parcel and distance from parcel centroid to nearest bus stop, it represents a negative relationship. Since p-value is less than 0.05, it indicated that there is significant relationship. Mixed zone has stronger negative relationship than residential zone.

Second, when it comes to the correlation between appraised unit value of parcel and number of light rail stations within one half mile distance, it represents a positive relationship. The p-value of 0.05 also shows a significant relationship between them. Residential zone has stronger positive relationship than mixed zone. Furthermore, in mixed zone, the relationship between appraised unit value of parcel and closest distance from parcel centroid to light rail station represents a negative relationship. However, in residential zone there is no relationship between them.

Third, in commuter rail system, only mixed zone has positive relationship between appraised unit value of parcel and the number of commuter rail stations within one half mile distance since p-value is less than 0.05. In addition, for residential, commuter rail system is not related to appraised unit value of parcel for residential zone.

Therefore, according to the correlation results, for mixed zone, the appraised unit value of parcel increases as the number of LEED qualified transit stops increases (bus, light rail, and commuter rail). In addition, the appraised value increases as the distance to LEED qualified bus stops light rail stops decreases. For residential zone, the appraised unit value of parcel increases as the number of LEED qualified bus and light rail stations increases. Furthermore, the appraised unit value of parcel increases as the distance to LEED qualified bus stops decreases.

6.1.2 Regression Models for Mixed and Residential Zones

In the predictive model for mixed zone, six independent variables were taken in the predictive model. An adjusted R-square of the transformed model was 0.713, which indicates that 71.3% variability in transformed unit value of parcels could be explained by these variables. The model is as follows:

Predicted appraised unit value of an unimproved parcel = [(1.339 + 0.027·(Number of bus stops) + 0.036·(Number of light rail stations) + 0.013·(Number of commuter rail stations) - 0.751·(Closest distance from the parcel centroid to bus stop) – 0.007·(Closest distance from the parcel centroid to light rail station)- 0.0008·(Area)]$^{(1/0.1)}$

For the predictive model of residential zone, an adjusted R-square was 0.622 thus the independent variables together accounted for 62.2% variability in the transformed unit value of parcels. The model is as follows:

Predicted appraised unit value of an unimproved parcel = [(1.043 + 0.17·(Number of bus stops) + 0.546·(Number of light rail stations) - 0.154·(Closest distance from the parcel centroid to bus stop) – 0.0006·(Area)]$^{(1/0.3)}$

The predicting models for mixed and residential zones were significant that suggests that the components of LEED-NC PTA criteria, number and distance from parcels, this could affect land development strategies. Furthermore, the findings of this study were similar to both studies of Park and Joshi. Therefore, this study could be strengthened the results of the previous studies.

In addition, an appraised unit value of parcels in San Francisco County can be estimated by 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.

6.2 Recommendations

An adjusted R-square was 0.713 and 0.622 for mixed and residential zones respectively. It indicated that there are some unknown factors for regression models.

Therefore, to find out best fit models for predicting appraised unit value of parcel in San Francisco County, it is meaningful to use other possible variables such as other LEED criteria, household income, the level of education, etc.

This study only focused on unimproved appraised land value of 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 improvement land value by using reliable data, it could be useful for developers to predict appraised land value of parcels. In addition, this study focused on mixed and residential zone. Commercial zone was not considered in this study. Therefore, it is necessary to examine the impact of LEED-NC PTA on appraised unit value of parcels for commercial zone.

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 parcel. Since Portland and Seattle was ranked first and third position with many LEED-NC projects according to US city sustainability rankings (People-Powered Sustainability Guide 2011). Therefore, these cities would more accurately investigate the economic impact of LEED-NC criteria on appraised unit value of parcels.

REFERENCES

Baranzini, A., and Schaerer, C., (2011). “A sight for sore eyes: Assessing the value of view and land use in the housing market.” *Journal of Housing Economics*, 20(19), 191-199.

BART. (2011). “Quarterly weekday average exits.” San Francisco Bay Area Rapid Transit District. http://bart.gov/docs/Quarterly_Exits_Q320 10.pdf. (April 4, 2011).

Benson, E. D., Hansen, J. L., Schwartz Jr., A. L., and Smersh, G. T., (1998). “Pricing residential amenities: The value of a view.” *Journal of Real Estate Finance and Economics*, 16(1), 55–73

Bill, R. (1994). “Multimedia GIS-definition, requirements and applications.” *The 1994 European GIS yearbook*, Taylor and Francis, London, UK.

Bose, S. (2009) “FY 2006-2007 third quarter financial results and year-end projection.” Municipal Transportation Agency, http://www. sfmta.com/cms/rbudget/documents/ FY2006-073rdqtrFinancialResultsyearend. (March 9, 2011).

Bramble, L. (2011). “How Do I Raise the appraisal value of a home.” Demand Media. http://homeguides.sfgate.com/raise-appraisal-value-home-remodeling-1296.html (Oct 2, 2011)

California State Public Data. (2011). “Geospatial clearing house” Atlas, http://ww w.atlas.ca .gov /download.html (April 18, 2011)

Caltrain. (2011). “Ridership.” Caltrain. http://www.caltrain. com/about/statsandreports /Ridership.htm (March 9, 2011).

Castro, L. T. (2011). “Market value vs. appraised value.” Demand Media, http://homeguides.sfgate.com/market-value-vs-appraised-value-1206.html (Oct 2, 2011).

Census 2000. (2000). “Population, housing units, area, and density for counties: 2000 Data Set: Census 2000 Summary File 1 (SF 1) 100-Percent Data.” U.S. Census Bureau, http://www.factfinder.census.gov (March 13, 2011).

Cervero, R. (1998). *The Transit Metro polis: A Global Inquiry*. Island Press. Washington D.C.

Cervero, R., and Duncan, M. (2004). “Land value impact of rail transit services in Los Angeles County.” *Report 11*. National Association of Realtors Urban Land Institute. Washington D.C.

Dunn, C. (2010). “SanTrans routes and schedules.” SamTrans, http://www.samtran s.com/ (March 8, 2011).

Gatzlaff, D., and Smith, M. (1993). “The impact of the Miami Metrorail on the value of residences near station locations.” *Land Economics*, 69(1), 54-66.

Geoghegan,J., (2002). “The value of open spaces in residential land use.” *Land Use Policy*, 19(1), 91–98.

Golden Gate Transit. (GGT 2011). “Golden Gate transit statistics.” GGT, http://www.goldengatetransit.org/researchlibrary/statistics.php (April 3, 2011).

Gonchar, J. (2005). “Rapidly evolving rating system draws applause and criticism.” *ENR: Engineering News-Record* (April 3, 2011).

Guerra, T. (2011). “Assessed value vs. appraised value of home.” Demand Media. http://homeguides.sfgate.com/assessed-value-vs-appraised-value-home-6873.html (Oct 2, 2011).

Hellawell, E., Kemp, A., and Nancarrow, D. (2001). “A GIS raster technique to optimise contaminated soil removal.” *Engineering Geology*, 60(1), 107-116.

Howe, J. C. (2010). “Overview of green buildings.” *National Wetlands Newsletter*, 33(1), 161-165.

Irwin, G. E., (2002). “The effects of open space on residential property values.” *Land Economics*, 78(4), 465–480.

Joshi, B., (2009), “Prediction of unit value of unimproved parcels of Harris County, Texas using LEED sustainable sites criteria of public transportation access.” Thesis, Texas A&M University, TX.

Kibert, C.J. (2005). *Sustainable Construction – Green Building Design and Delivery*, John Wiley & Sons, NY.

Landis, J. Guhathakurta, S., and Zhang, M. (1994). "Capitalization of transit investments into Single-Family Home Prices." *Working Paper.* University of California Transportation Center, CA.

Lutzenhiser, M., and Netusil, N. R., (2001). "The effect of open spaces on a home's sale price." *Contemporary Economic Policy*, 19(3), 291–298.

McMillen, D., and McDonald, J., (2004). "Reaction of house prices to a new rapid transit line: Chicago's midway line1983–1999." *Real Estate Economics*, 32(3), 463-486.

Metropolitan Transportation Commission (MTC). (2010). "Maps and data." MTC, http://www.mtc.ca.gov/maps_and_data/GIS/data.htm (March 3, 2011).

Park Y, J. (2009), "Predicting the unit appraisal value of the unimproved and private land in the city of Houston by LEED sustainable site credits." Dissertation, Texas A&M University, TX.

People-Powered Sustainability Guide. (2011). "2008 US city sustainability rankings." Sustain Lane, 2011. http://www.sustainlane.com/us-city-rankings/overall-rankings. (June 7, 2011).

Rubenstein, M. (2011). "Market value vs. appraised value." Demand Media, http://homeguides.sfgate.com/difference-tax-appraised-value-property-market-value-1200.html (October 2, 2011).

San Francisco Municipal Transportation Agency (SFMTA). (2010). "Routes and schedules." SFMTA, http://www.sfmta.com/cms/mroutes/ indxrout.htm (February 3, 2011).

San Francisco Planning Department. (2011). "San Francisco Municipal Code." SFGOV, http://www.sfplanning.org/ (April 8, 2011).

Schedler, A., and Udall, R. (2005). "LEED is broken. Let's fix it." Aspen, http://www.aspensnowmass.com/environment/news.cfm (April 8, 2011).

Schultz, S. D., and King, D. A., (2001). "The use of census data for hedonic price estimates of open-space amenities and land use." *Journal of Real Estate Finance and Economics*, 22(3), 239–252.

Seiler, M. J., Bond, M. T., and Seiler, V. L., (2001). "The impact of world class great lakes water views on residential property values." *Appraisal Journal*, 69,287–295.

U.S. Green Building Council (USGBC). (2007). "What LEED is?" USGBC, http://www.usgbc.org/DisplayPage. aspx?CMSPageID=19887 (April 27, 2011).

U.S. Green Building Council (USGBC). (2009). "LEED-NC for new construction reference guide version 3.0" *Report 3*. U.S Green Building Council (USGBC). Washington D.C.

U.S. Green Building Council (USGBC). (2010). "LEED version 3.0." USGBC, http://www.usgbc.org/DisplayPage.aspx?CMSPageID=1970 (January 2, 2011).

U.S. Green Building Council (USGBC). (2011). "LEED projects & case studies." USGBC, 2011. http://www.usgbc.org/LEED/Project/ (April 3 2011).

Yu, S. M., Han, S. S., and Chai, C. H., (2007). "Modeling the value of view in real estate valuation: a3-DGIS approach." *Environment and Planning B: Planning and Design*, 34(2), 139–153.

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