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The Impact of LEED-Energy Star Certified Office Buildings on the Market Values of Neighboring Areas in New York City

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ABSTRACT

Green building certifications are being adopted widely, and existing research continues to show an array of benefits to stakeholders of green certified buildings. However, little attention has been paid thus far to the effects these buildings may have on their surrounding neighborhoods economically. This research examined the effect of LEED and/or Energy Star certification on the neighborhoods surrounding certified office buildings from an economic standpoint with spatial and statistical analyses. This research showed the unit market value of LEED and/or Energy Star certified office buildings and the parameters of LEED and/or Energy Star certification had statistically a positive impact on the median unit market value of their neighborhood areas. The findings can provide useful insights into the possibilities for additional economic benefits of their neighborhoods, encouraging a win-win approach that enhances the local real estate market.

Keywords: LEED and/or Energy Star certified office building, market value, neighborhood area, walking distance, median unit market value

INTRODUCTION

The purpose of green building certifications is changing to support efforts to obtain sustainability because the needs of building stakeholders are also expanding from a simple focus on better eco-friendly performance. The benefits of Leadership in Energy and Environmental Design (LEED) or Energy Star, two leading green building certifications, have been investigated by several researchers [1, 2, 3, 4, 5, 6]. However, little research has been undertaken to study the economic benefits of Energy Star certification or LEED for the surrounding neighborhood or local community from an economic perspective for a sustainable neighborhood. To ensure the sustainability of green building certification, it is necessary to meet the triple bottom lines of sustainability, environmental, economic, and social aspects [7, 8]. Based on the triple bottom lines of sustainability, this research focused on the local economic aspects of sustainability, which were related to people and profit by exploring the question of how

changes in LEED and/or Energy Star certified office buildings have an economic impact on their surrounding neighborhood to encourage the mutual growth of the LEED and/or Energy Star certified office buildings and their neighborhoods as a win-win approach. This study is to expand the concept of "green" beyond simple environmental performance to include economic factors by examining their impact from a fresh perspective and thus initiating a more comprehensive investigation of the leading green building certifications that takes into account not only the principles of environmentalism, but also the associated economic developments. As a result, this research is expected to affect the sustainability of the LEED and Energy Star certifications by encouraging building stakeholders, neighbors, and governments to appreciate the economic opportunities or benefits of LEED or Energy Star certification such as economic revitalization of local community for the local real estate market. In particular, the result of this research can be useful to support the decision-making processes of neighbors in the local community and local government agencies from both the economic and environmental standpoints.

BACKGROUND

The Impact on the Property Value of a Building with Various External Features in the Existing Environment

The property values are determined by the interaction of sellers and buyers in the real estate market as the law of supply and demand [9, 10]. The property value of a particular building is also affected by the property commodity itself and the external environmental features. External environmental determinants of property value can be classified according to four different categories as follows: social factors, physical factors, economic factors, and government and political factors [9]. Several researchers have examined the effect of external features in the existing environment on the determination of the property value of each building based on different environmental features. Lin et al. (2009), Chang and Chou (2010), Chun et al. (2011), Saphores and Li (2012), Suh et al. (2013), Freybote et al. (2015), and Suh et al. (2019) have investigated the correlation between the changes of property values and particular external environmental features in specific areas. Taking the property values of either residential or commercial properties, most of these studies concluded that the property values could be changed either positively or negatively due to the addition of new appearance or tangible or intangible external environmental features. Table I presents that one common point of external environmental features in these previous studies was all were related to the quality of human life.

Lin et al. (2009) concluded that a foreclosure had a negative impact on residential property values in the neighborhood, and they also found that the strength of negative impact caused by the foreclosure was inversely proportional to the distance from the foreclosed property, citing a distance of 0.9 km (about 2,700 ft) as the effective radius of properties suffering a significant negative impact. Chang and Chou (2010) reported that factors associated with the project's greenness had a positive impact on the building's reputation and the local urban real estate market.

TABLE I. EFFECTS OF EXTERNAL ENVIRONMENTAL FEATURES ON NEIGHBORHOOD PROPERTY VALUES

	Response	Measurement	Effects
Lin et al. (2009)	Residential property values	Foreclosure	Negative impact on property values of neighborhood area.
Chang and Chou (2010)	Neighborhood property values	A building's green design	Positive impact on the property values of neighborhood area due to the environmental improvement.
Chun et al. (2011)	Commercial property values	Visible space	Positive impact on the property values due to a better quality of life.
Saphores and Li (2012)	Residential property values	Urban green area	Positive impact on the property values due to a better quality of life.
Suh et al. (2013)	Commercial property values	LEED certification	Positive impact on property values of neighborhood area.
Freybote et al. (2015)	Residential property values	LEED neighborhood certification	No impact on the property values of LEED certified/non-certified condos in LEED neighborhood certified areas.
Suh et al. (2019)	Adjoining property values	LEED certified office building	Positive impact on the property values due to LEED certified office buildings.

The Impact on Local Property Values of a Building with Good Walkability

Demographic factors were a critical determinant of the supply and demand curve for a specific building. O'Sullivan (2009) emphasized the importance of demographics for office property rental values due to the proximity to the central business district (CBD), the higher density of population, and the higher productivity of employees of the service provider and the service recipient. For these reasons, the proximity to the CBD is related to the demographic factors, and people in a metropolitan city generally prefer a walking distance to a driving or biking distance from their living space to their working place [18]. Leinberger and Lynch (2014) argued that NYC had the second highest walkable urban environment of all major U.S. cities and the walkability of office and retail workers should play a core role in the decision making for workplace locations in NYC. Therefore, the walkability has been the focus of several investigations into the effect of proximity between a subject building and a target building. New York City achieved the highest score in the U.S. and was ranked the most walkable city in 2011 and 2014[1]. The score also indicated that the NYC public transportation systems were capable of assisting the city's residents to commute to their workplaces and those residents were looking for homes in walkable areas. NYC's subway system has the greatest ridership among all the transportation systems in NYC[2], and NYC Metropolitan Transportation Authority (NYCMTA) (2013) mentioned that any location on the island of Manhattan was within a 15-minute walk of a subway entrance. Subway commuters could foster more livable communities through the contacts they had with others in their neighborhood, thus creating strong neighborhood centers that were economically stable, safe, and productive [21]. Therefore, the proximity to a subway entrance could be a source of satisfaction for commuters who work at an office building that is near a subway entrance. Researchers have suggested a common proximity

1) http://www.walkscore.com/NY/New_York
2) MTA.info: Subway and Bus Ridership, http://web.mta.info/nyct/facts/ridership/

that satisfy commuters, 0.25 miles, as below in Table II.

TABLE II. WALKABLE DISTANCE CONSIDERED CONVENIENT BY PEDESTRIANS

Federal Highway Administration (2002)	0.25 miles (the maximum convenient distance)
Dill (2003)	0.25 miles, or 5-10 minutes
Sohn et al. (2012)	0.25-0.3 miles

The Market Value of Properties in New York City

The definition of market value is the most probable price of a property determined in a competitive and open market under stable conditions where buyer and seller are serious participants and can access sufficient knowledge of the property, and where the price is not affected by excessive stimulus [25]. Market value could also be defined as the meeting point between the maximum price a buyer is willing to pay and the minimum price a seller is willing to accept [24]. In other words, "market value" could be considered as either the meaning of the transaction price or the actual sales price. Several researchers have argued that the real transaction price or an actual sales price is the most valuable data required to make their research more realistic. The Appraisal Institute (2002) presented two major reasons for there being a tenuous correlation between assessed value and market value: 1) outdated mass valuations for estimating assessed values; and 2) fractional assessment ratios, partial exemptions, and inappropriate factors considered by appraisers. However, many of the previous studies have used assessed values rather than the data from real transaction prices or actual sales prices. The tax base market value data was shown to provide a useful approximation to willingness to pay for a residential property because of the comparable sales approach and other similar agencies for all residential properties [27]. Aydin et al. (2010) also gave two reasons why they considered assessed values to be appropriate for their research: 1) the limited amount of data on actual sales prices during a limited time period; and 2) the correlation between actual sales value and tax appraisals. Dermisi (2009) put forward four reasons for using assessor-generated market values when studying LEED certified buildings: 1) the difficulty in obtaining actual transaction prices of properties; 2) little or no transaction history for recently constructed buildings; 3) the lack of awareness of the economic benefits to be gained from LEED certification; and 4) the consequences when comparing the results of current and future research using the same type of assessed market values. In a similar vein, Matthews (2006) used tax assessment data to take advantage of the linkage of tax parcel Geographic Information System (GIS) mapping data and the entire property tax base assessed value over the entire research area. Kim and Son (2011) and Gibbons et al. (2014) agreed, noting that although recently the market value has affected estimates of rental rates, the rental rates should also have a fundamental impact on determining the market value of property. NYC's DOF makes serious efforts to minimize the gap between their annual estimates of market values and actual sales prices or transaction prices by estimating the market value of properties in NYC using different methods depending on the tax classes of the buildings concerned, taking into account changes in building conditions and damage to structures in areas of special flood hazard. NYC's Independent Budget Office

(IBO) provides two different ways of reaching the assessed values determined by NYC's DOF: the actual assessed value, referred to as the estimated market value, and the transitional assessed value, or assessed value[3]. They considered the actual assessed value to be equal to the current estimated market value, which fully reflects all annual changes. In addition, NYC's IBO regards the transitional assessed value to be more stable than the actual assessed value due to the two mechanisms involved, namely the cap on the assessments and the phasing in of changes in assessed value. The market values used by NYC's DOF already include the physical building characteristics when they estimate the market value of individual properties. As a result, this research utilized one estimated value, market value, when calculating the property tax for individual properties.

PROBLEM STATEMENT

Several researchers have found that LEED or Energy Star certifications had a positive impact on the property values of the certified buildings [1, 4, 5, 33, 34, 35], and other researchers have focused on the impact of external features in existing environments on the property values near the external features [11, 12, 13, 14, 36]. The review of the relevant literature identified a research question that has not yet been addressed concerning the possibility of impacts of LEED and/or Energy Star certified office buildings on neighborhood property values, depending on the proximity between the nearby buildings and the LEED and/or Energy Star certified office building. LEED and/or Energy Star certification are likely to be an independent external feature in the existing environments as a foreclosure. Thus, this research explored the economic benefits of LEED and/or Energy Star certified office buildings by examining their effect on the median unit market values of buildings in their neighborhoods for the local real estate market and the community.

METHODOLOGY

Study Area

NYC has the second largest number of LEED certified buildings in the U.S. and has one of the highest numbers of buildings achieved Energy Star certification, with the 4th largest number of Energy Star certified building in 2012 among U.S. metropolitan cities. Approximately 80 percent of LEED certified buildings in NYC are located in Manhattan, and Energy Star certified buildings present a similar trend in this city. At present, almost 90 percent of the office buildings having LEED and/or Energy Star certifications in NYC are located on the island of Manhattan.

Data Sources and Variables

It was necessary to maintain accurate and consistent data for research projects due to the slightly different information available for the screed population of LEED and/or Energy Star certified office buildings from various

3) https://www1.nyc.gov/site/finance/taxes/property-determining-your-market-value.page

organizations, so the information on LEED certified office buildings was gathered solely from the USGBC database and that for the Energy Star certified office buildings from the EPA database. The information on the physical characteristics of buildings in the neighborhood areas and the data on Geographic Information System (GIS) were provided by NYC's Department of City Planning (DCP) database. NYC's DCP have updated GIS data set regularly, and the most recent update of the GIS data set was in October 2013. The market value data set provided by NYC's Department of Finance (DOF) was available to download from their website for the fiscal years (FY)[4] 2009 through 2015 and request by Freedom of Information Law (FOIL) for FY 2007 to FY 2008. Table III shows that the median market value for a specific neighborhood was assigned as the dependent variable and the other characteristics of LEED and/or Energy Star certified buildings as independent variables in both the hedonic price model and linear mixed effect model.

TABLE III. THE DESCRIPTION OF VARIABLES AND DATA SOURCE

Variable		Variable name	Description & numerical values	Data source
Independent variable	LEED	LEED certification level	The level of LEED certification (Certified:1/Silver:2/Gold:3/Platinum:4)	USGBC
		LEED certification coverage	Certification for part of the building or a whole building (Partial:1/Full:2)	USGBC
		LEED certified year	Certified years (Non-certified year: 0/Certified year:1)	USGBC
	Energy Star	Energy Star certified year	Energy Star certification is reevaluated annually. (Non-certified year:0/Certified year:1)	EPA
	Market value	Unit market value of LEED and/or Energy Star certified office building in the neighborhood (2007-2013)	Market value of property estimated by NYC's DOF from FY 2007 through FY 2013 (in USD) is divided by the property area (building).	NYC's DOF
Dependent variable	Market value	Median unit market value of buildings in the neighborhood (2007-2013)	Market value of each individual property estimated by NYC's DOF from FY 2007 through FY 2013 (in USD) is divided by the property area (building) to obtain the unit market value for each property. The median value is then calculated for all properties in the surrounding neighborhood. Using the median value avoids the limitations of the mean value theorem.	NYC's DOF

Defining the Coverage and Level of LEED Certification for a LEED Certified Office Building Achieving Multiple LEED Certifications

LEED certification consists of two major characteristics, the coverage and level, both of which specifically indicate differences in LEED certification between LEED certified buildings. In addition, LEED certification allows the achievement of a higher LEED certification that enhances the level of LEED certification or improves the LEED certification coverage from part of building to the whole building. 15 of the LEED certified office buildings in the screened population of this study achieved at least two LEED certifications during the study period.

4) The fiscal year is from July 1 through June 30 the next year for all properties in NYC.

Therefore, this study redefined the coverage and level of LEED certified office buildings when they achieved extra LEED certifications with a different coverage or the higher level of LEED certification. LEED certification for a whole building took precedence over LEED certification for part of the building for the coverage, and the higher level of LEED certification was given priority when defining the level of LEED certification awarded to an office building. Table IV lists the results of defining the coverage and level of 15 LEED certified office buildings.

TABLE IV. THE DEFINITION OF THE COVERAGE AND LEVEL OF 15 LEED CERTIFIED OFFICE BUILDINGS ACHIEVED MULTIPLE LEED CERTIFICATIONS

No. of LEED certifications	LEED certifications (Coverage/Level)								Defining the coverage and level of LEED certified office building (Coverage/Level)
Two LEED certifications	1st	Full/Certified	2nd	Partial/Gold	3rd	N/A	4th	N/A	Full/ Certified
	1st	Full/Certified	2nd	Full/Silver	3rd	N/A	4th	N/A	Full/Silver
	1st	Full/Silver	2nd	Full/Gold	3rd	N/A	4th	N/A	Full/Gold
	1st	Full/Gold	2nd	Partial/Certified	3rd	N/A	4th	N/A	Full/Gold
	1st	Partial/Gold	2nd	Full/Silver	3rd	N/A	4th	N/A	Full/Silver
	1st	Full/Certified	2nd	Full/Gold	3rd	N/A	4th	N/A	Full/Gold
	1st	Full/Silver	2nd	Partial/Silver	3rd	N/A	4th	N/A	Full/Silver
	1st	Full/Silver	2nd	Partial/Gold	3rd	N/A	4th	N/A	Full/Silver
	1st	Full/Silver	2nd	Partial/Gold	3rd	N/A	4th	N/A	Full/Silver
	1st	Full/Gold	2nd	Full/Gold	3rd	N/A	4th	N/A	Full/Gold
	1st	Partial/Gold	2nd	Full/Silver	3rd	N/A	4th	N/A	Full/Silver
	1st	Full/Silver	2nd	Partial/Gold	3rd	N/A	4th	N/A	Full/Silver
	1st	Full/Silver	2nd	Partial/Gold	3rd	N/A	4th	N/A	Full/Silver
Three LEED certifications	1st	Full/Gold	2nd	Partial/ Platinum	3rd	Partial/ Platinum	4th	N/A	Full/Gold
Four LEED certifications	1st	Partial/Silver	2nd	Full/Gold	3rd	Partial/ Platinum	4th	Partial/ Platinum	Full/Gold

Defining the Neighborhood Area

The definition of neighborhood is a district or locality characterized by similar or comparable land uses and homogenous groupings, with neighborhood boundaries that consist of well-defined natural or man-made barriers, land use changes or the characteristics of the inhabitants [25, 26]. Walkable distance is a core external environmental feature that is widely used to estimate the market value of a certain building because the walkability directly relates to a property value. Consequently, the neighborhood of a LEED and/or Energy Star certified office building was taken to be the walkable distance from that building, and the neighborhood boundary corresponded to the maximum walkable distance. The radius of the neighborhood of individual LEED and/or Energy Star certified office buildings was therefore taken to be a quarter of a mile (0.25 miles) from that building to define the neighborhood area for the purposes of this research.

Research Method

Two major approaches were used in this research: spatial and statistical approaches. A spatial analysis approaches was used to identify the buildings located within the boundary of the neighborhood based on the geographic information of the LEED and/or Energy Star certified office building. The hedonic price model and the linear mixed effect model were utilized to identify any correlations between the independent variables and the dependent variable.

A Spatial Analysis Approach Applied

ArcGIS 10.1 was used to establish the precise spatial distribution of LEED and/or Energy Star certified office buildings in Manhattan NYC, and to identify individual buildings within their surrounding neighborhoods, a 0.25-mile-radius. In addition, an overall data sheet that includes all the primary information to be applied to the statistical analysis was constructed.

A Statistical Analysis Approach Applied

The hedonic price model is useful to measure the value of the environment using cross-sectional data for land values [37], and Can (1992) and Lee et al. (2009) noted that the hedonic price regression model was one of the most common approaches used to measure the effect of neighborhood factors and to encompass the heterogeneous characteristics of the socio-economic and physical make-up of a neighborhood. In practice, several researchers have utilized the hedonic price model to investigate the effect of external features in the existing environment on the property values of commercial or residential property. [13, 40, 41]. The hedonic price model provides four different model equations for transforming the data sets in order to identify the most appropriate hedonic price model; Linear, Log-linear, Semi-log, and Log-log. In addition, the linear mixed effect model is helpful when analyzing repeated measure data or cross-sectional data in various research disciplines [42]. As each subject provided numerous responses, these responses are correlated, which is explicitly forbidden by the assumptions of the standard ANOVA and regression models. Moreover, it becomes possible to estimate random intercepts for each subject, control correlated data, and deal with unequal variances by using the linear mixed effect model [43]. Researchers can also infer the fixed effects that are the primary focus of this research as well as random effects that are not central to the investigation but are still of interest using only a small set of levels through the linear mixed effect model [44]. The statistical methods applied were based on the specific data for these independent variables taking into account the status change from pre-certified LEED and/Energy Star to post-certified LEED and/or Energy Star to quantify the impact of a building achieving LEED and/or Energy Star certification on the market values of buildings in the surrounding neighborhood.

RESULTS

Geographical Approach Method Analysis

The geographical approach was used to determine the distribution of LEED and/or Energy Star certified office buildings utilizing a street-scale map of Manhattan, NYC, and to identify buildings in the surrounding neighborhood of each in Figure I through Figure XVIII.

Of the 171 LEED and/or Energy Star certified office buildings in Manhattan, 149 were selected for inclusion in this study as the screened population group. Most of the screened population group were located around the midtown area, with the rest dispersed around the west-southern area of Manhattan along the coastline. Interestingly, only one Energy Star certified office building was located at the northern end of Manhattan. As shown in the previous exhibits, most of the neighborhood areas included several different subway entrances, which indicated that most of buildings in those neighborhood areas were indeed located within a walkable distance of the closest subway entrance. According to their precise geographical locations, the unit market value of buildings in the same neighborhood would have a roughly equivalent impact due to their proximity to the closest subway entrance. Only three neighborhoods surrounding LEED and/or Energy Star certified office buildings have no subway entrance within their neighborhood boundary, as shown in Figure XIX, XX, and XXI. Although the greatest distance of a building in the neighborhood to the closest subway entrance was about 0.8 miles, or 17 minutes, as measured by the recommended travel mode function for a pedestrian on Google Map, the greatest straight-line distance between the

FIGURE I. DISTRIBUTION OF LEED AND/OR ENERGY STAR CERTIFIED OFFICE BUILDING (OVERVIEW)

FIGURE II. DISTRIBUTION OF LEED AND/OR ENERGY STAR CERTIFIED OFFICE BUILDING (UPTOWN)

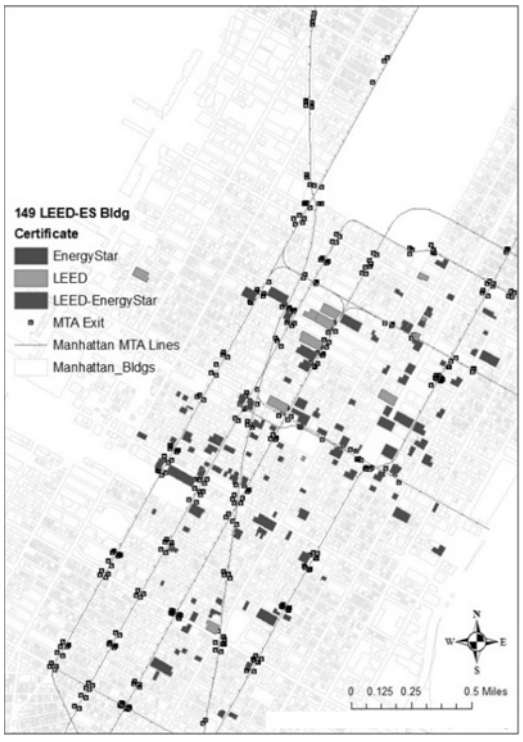

FIGURE III. DISTRIBUTION OF LEED AND/OR ENERGY STAR CERTIFIED OFFICE BUILDING (MIDTOWN)

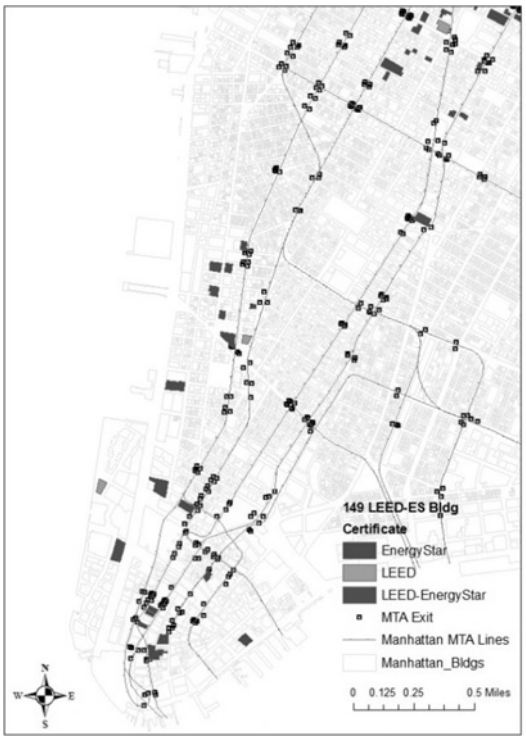

FIGURE IV. DISTRIBUTION OF LEED AND/OR ENERGY STAR CERTIFIED OFFICE BUILDING (DOWNTOWN)

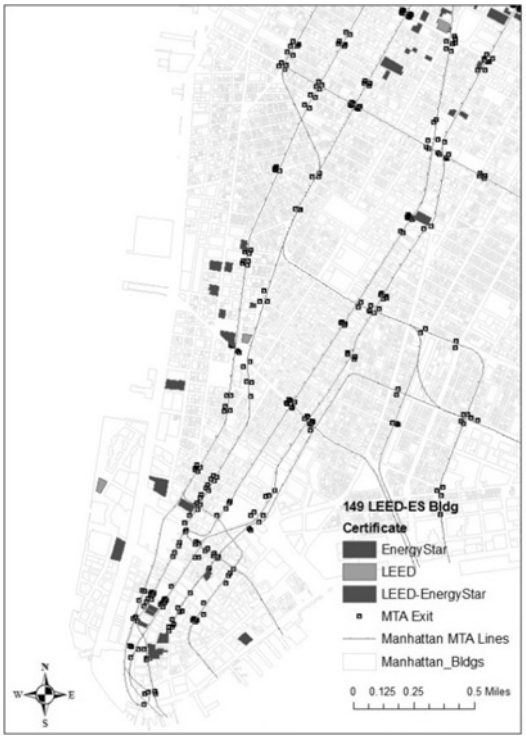

FIGURE V. DISTRIBUTION OF NEIGHBORHOOD OF LEED AND/OR ENERGY STAR CERTIFIED OFFICE BUILDING (OVERVIEW)

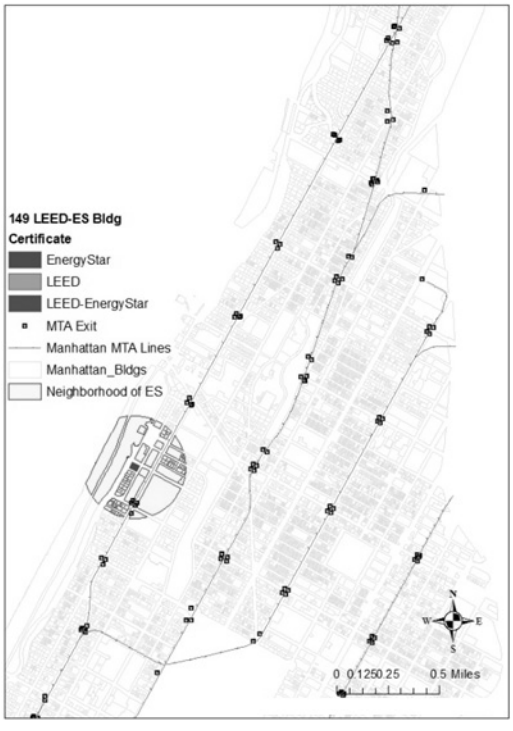

FIGURE VI. DISTRIBUTION OF NEIGHBORHOOD OF LEED AND/OR ENERGY STAR CERTIFIED OFFICE BUILDING (UPTOWN)

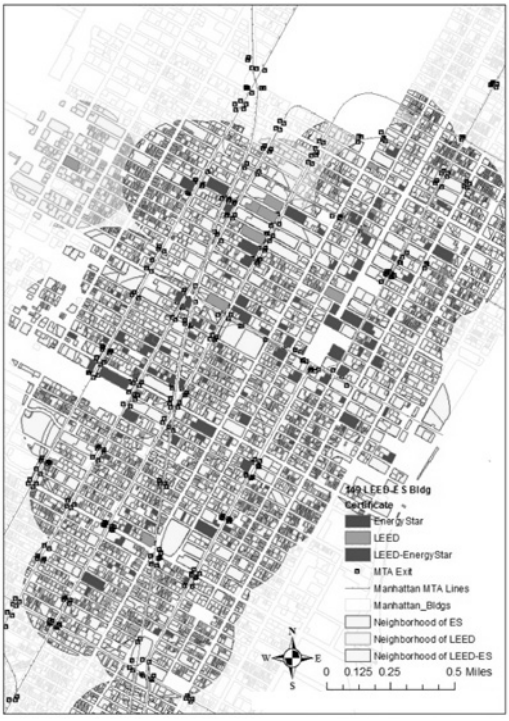

FIGURE VII. DISTRIBUTION OF NEIGHBORHOOD OF LEED AND/OR ENERGY STAR CERTIFIED OFFICE BUILDING (MID-TOWN)

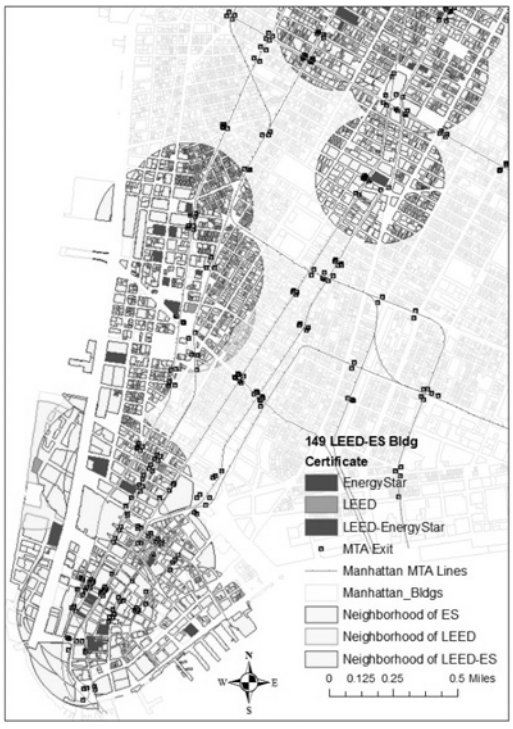

FIGURE VIII. DISTRIBUTION OF NEIGHBORHOOD OF LEED AND/OR ENERGY STAR CERTIFIED OFFICE BUILDING (DOWN-TOWN)

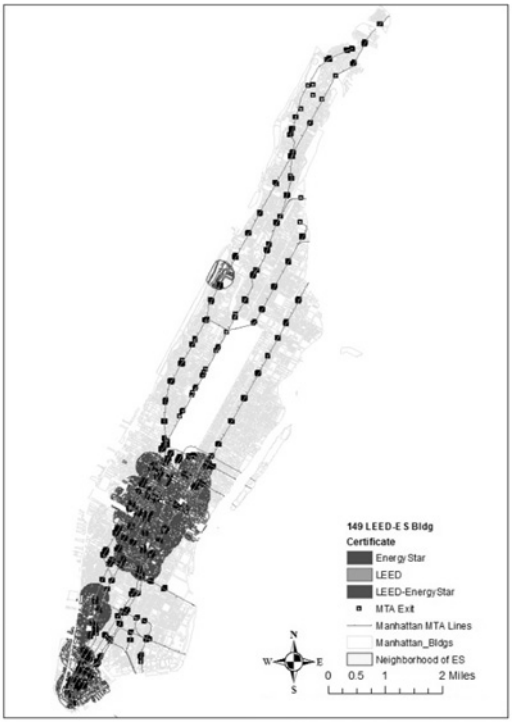

FIGURE IX. DISTRIBUTION OF NEIGHBORHOOD OF ENERGY STAR ONLY CERTIFIED OFFICE BUILDING (OVERVIEW)

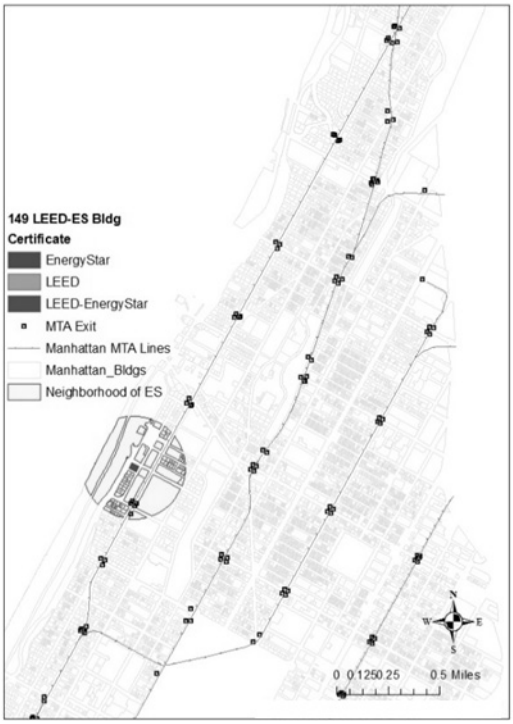

FIGURE X. DISTRIBUTION OF NEIGHBORHOOD OF ENERGY STAR ONLY CERTIFIED OFFICE BUILDING (UPTOWN)

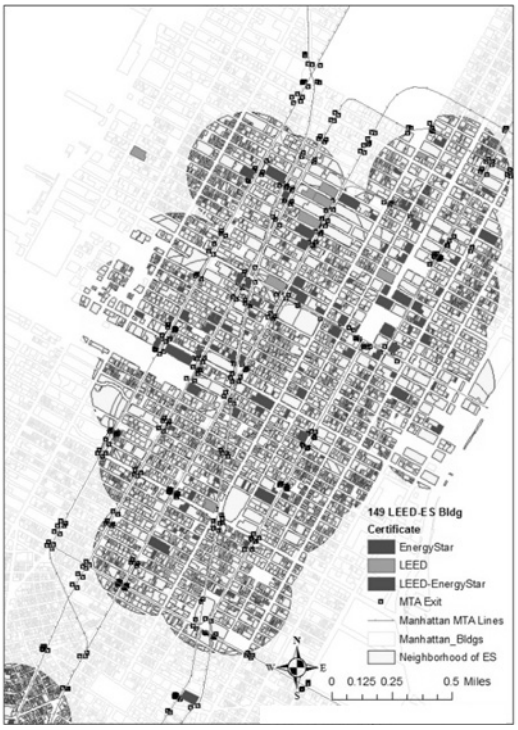

FIGURE XI. DISTRIBUTION OF NEIGHBORHOOD OF ENERGY STAR ONLY CERTIFIED OFFICE BUILDING (MIDTOWN)

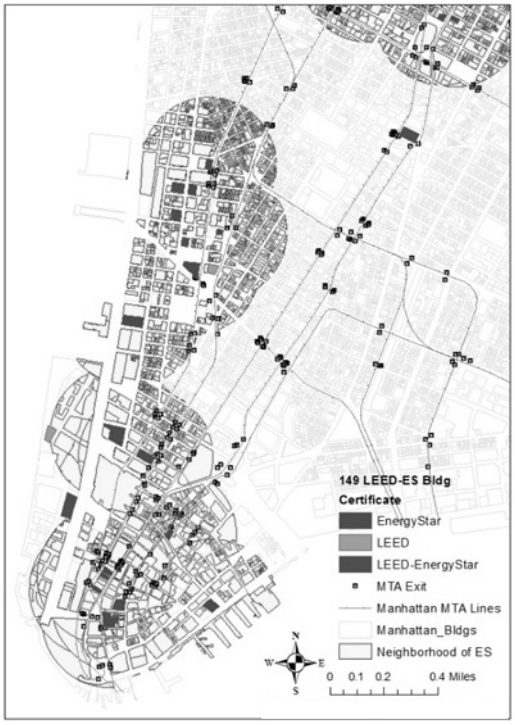

FIGURE XII. DISTRIBUTION OF NEIGHBORHOOD OF ENERGY STAR ONLY CERTIFIED OFFICE BUILDING (DOWNTOWN)

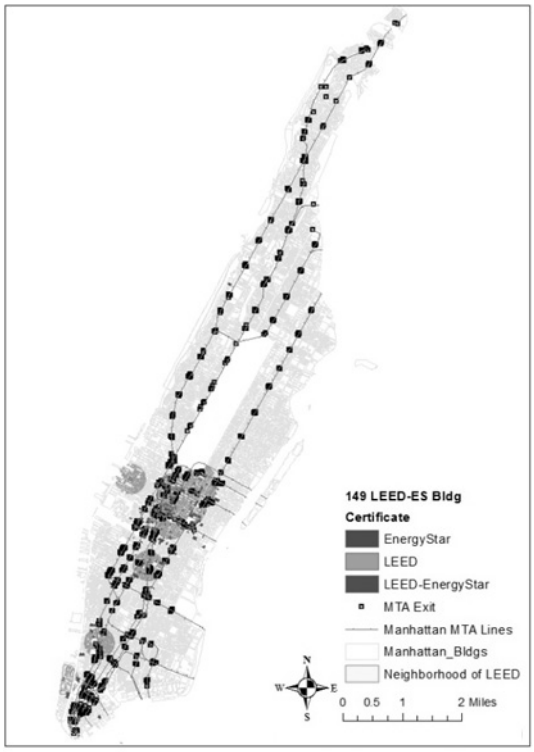

FIGURE XIII. DISTRIBUTION OF NEIGHBORHOOD OF LEED ONLY CERTIFIED OFFICE BUILDING (OVERVIEW)

FIGURE XIV. DISTRIBUTION OF NEIGHBORHOOD OF LEED ONLY CERTIFIED OFFICE BUILDING (MIDTOWN)

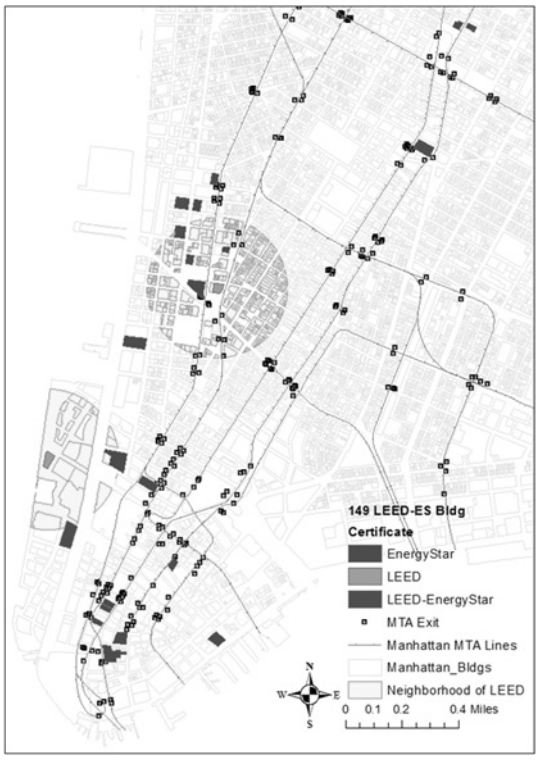

FIGURE XV. DISTRIBUTION OF NEIGHBORHOOD OF LEED ONLY CERTIFIED OFFICE BUILDING (DOWNTOWN)

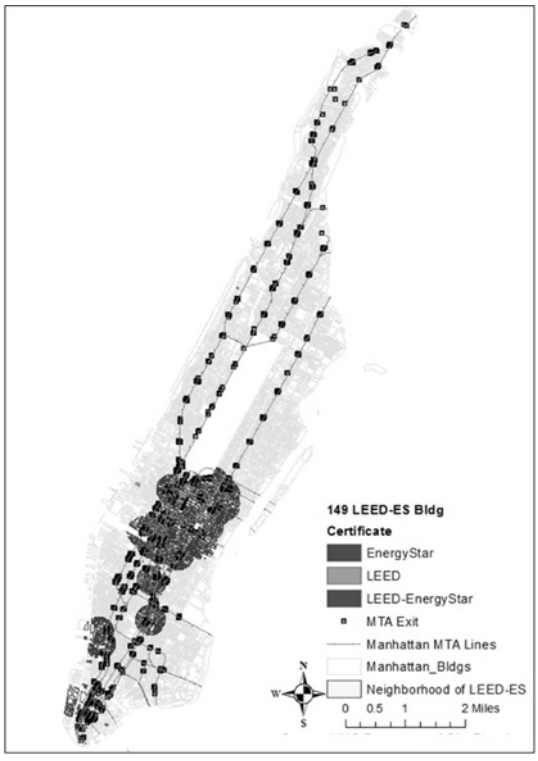

FIGURE XVI. DISTRIBUTION OF NEIGHBORHOOD OF LEED AND ENERGY STAR CERTIFIED OFFICE BUILDING (OVERVIEW)

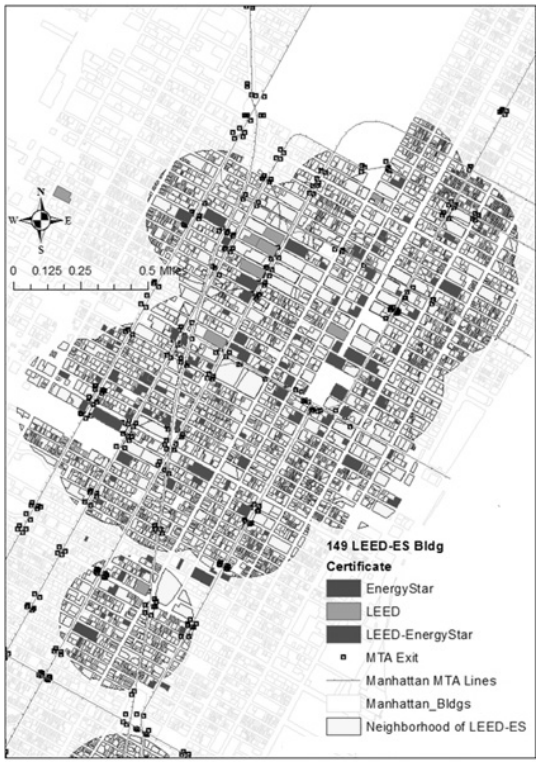

FIGURE XVII. DISTRIBUTION OF NEIGHBORHOOD OF LEED AND ENERGY STAR CERTIFIED OFFICE BUILDING (MIDTOWN)

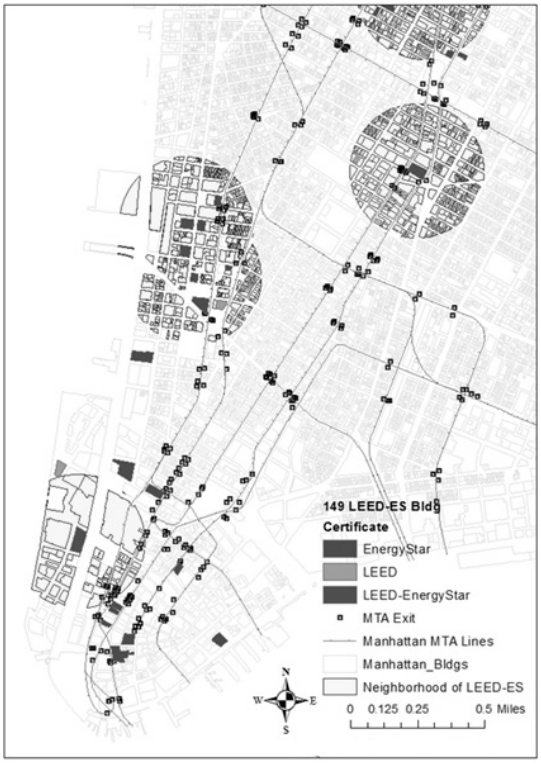

FIGURE XVIII. DISTRIBUTION OF NEIGHBORHOOD OF LEED AND ENERGY STAR CERTIFIED OFFICE BUILDING (DOWNTOWN)

same building and the nearest subway entrance was about 0.58 miles, calculated based on the geographic latitude and longitude of the start and end points, 166 W 46th St. and the Metropolitan Transportation Authority (MTA) subway station of 42nd St.-Port Authority Bus Terminal (Figure XXI). This research utilized the straight-line distance to determine the boundary of the neighborhood of a LEED and/or Energy Star certified office building; thus, the greatest distance of a building in the neighborhood to the closest subway entrance was also based on the straight-line distance in this research. Based on this research condition, it was reasonable to assume that a 0.58 mile-straight-line distance was a walkable distance in NYC in accordance with NYC's Metropolitan Transportation Authority, which considered a 15-minute walk to be acceptable. Consequently, all the buildings in every neighborhood surrounding a LEED and/or Energy Star certified office building were treated as being located within a walkable distance of the closest subway entrance, and this would therefore have a similar economic effect on the market values of every building in the neighborhood as an external environmental feature due to their equivalent convenient accessibility to the MTA subway system and the uniform satisfaction of subway transit commuters traveling to work in buildings in the neighborhood of a LEED and/or Energy Star certified office building.

The property market values provided by NYC's DOF already reflected most of the characteristics related to the internal building features and external environmental features surrounding the property, so the market value of a LEED and/or Energy Star certified office building already took into account the characteristics of its LEED and/or Energy Star certification indirectly via general economic variables which were considered annually when estimating the market value of buildings in NYC by NYC's DOF [45]. Moreover, the measurements of property value such as rental rates, sales price, occupancy rate, and resale value rate were impacted by achieving LEED and/or Energy Star certification, as demonstrated in several studies [1, 33, 34]. Consequently, the median market value of each building in the neighborhood also included every direct or indirect impact from the internal and external features. In addition, the high density of LEED and/or Energy Star certified office buildings in Manhattan, NYC resulted in a relatively close distance between each LEED and/or Energy Star certified office building. Thus, numerous overlapping areas between the neighborhoods of LEED and/or Energy Star certified office buildings existed. The above Figure XXII shows a case of overlapping areas of neighborhood of three different certified office buildings. The overlapping areas were identified as a limitation of statistical models for this research because this study focused on the impact of a LEED and/or Energy Star certified office building not on the individual unit market values of each building in its neighborhood and hence the median unit market value of the overlapping areas for nearby certified office buildings, but rather on the median unit market value of each certified building's neighborhood independently.

The results of the geographical approach method indicated that the 89 Energy Star only certified office buildings made up the largest group among the three different combinations of LEED and/or Energy Star certification. The

5) Overlapping neighborhood 1: Overlapping three certified office buildings (LEED certification only, Energy Star certification only, and LEED and Energy Star certifications), Overlapping neighborhood 2: Overlapping two certified office buildings (LEED certification only and Energy Star certification only), Overlapping neighborhood 3: Overlapping two certified office buildings (Energy Star certification only and LEED and Energy Star certification)

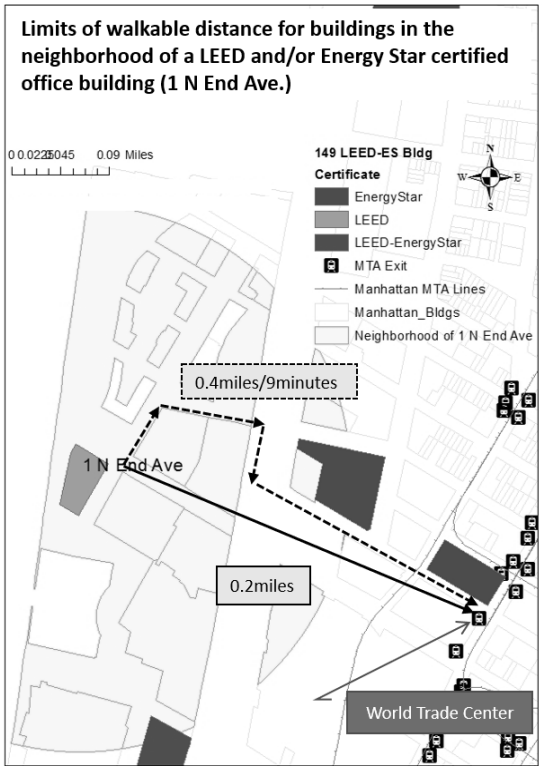

FIGURE XIX. NO SUBWAY ENTRANCE IN THE NEIGHBORHOOD OF 1 N END AVE

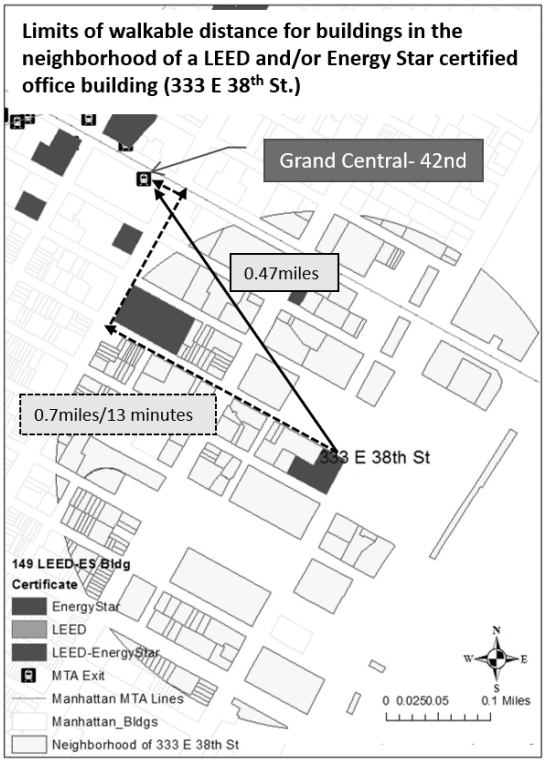

FIGURE XX. NO SUBWAY ENTRANCE IN THE NEIGHBORHOOD OF 333 E 38TH ST

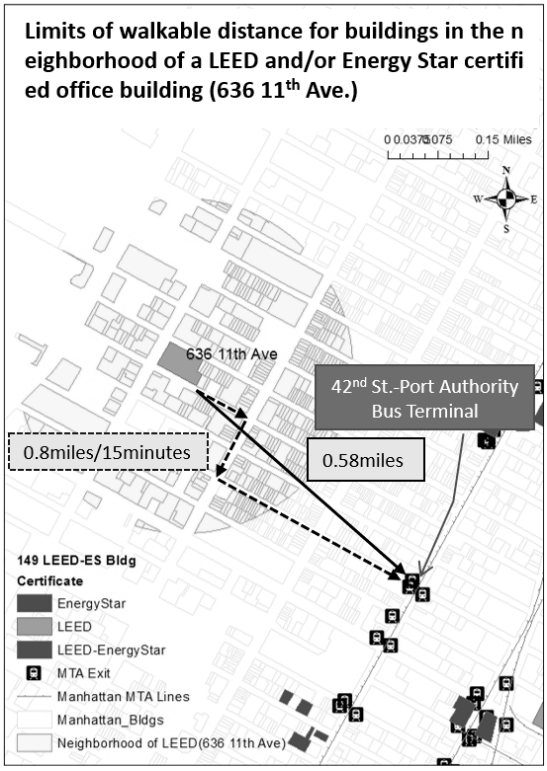

FIGURE XXI. NO SUBWAY ENTRANCE IN THE NEIGHBORHOOD OF 636 11TH AVE

FIGURE XXII. OVERLAPPING AREAS OF NEIGHBORHOODS OF LEED AND/OR ENERGY STAR CERTIFIED OFFICE BUILDINGS[5)]

proportion of buildings achieving at least Energy Star certification in the sample of this study was about 90.6 percent. In contrast, fourteen LEED only certified office buildings were included in the sample, and this group was smaller than 46 LEED and Energy Star certified office buildings. The results indicated that the average number of buildings in the neighborhood of each LEED and/or Energy Star certified office building was 521, and Table V shows the average number of buildings in the neighborhood for the three different combinations of LEED and/or Energy Star certification.

TABLE V. THE NUMBER OF LEED AND/OR ENERGY STAR CERTIFIED OFFICE BUILDINGS AND THE AVERAGE NUMBER OF BUILDINGS IN THE NEIGHBORHOOD FOR THOSE CERTIFIED OFFICE BUILDINGS IN MANHATTAN, NYC

	LEED certification only	Energy Star certification only	LEED & Energy Star certifications	Total
No. of certified buildings	14	89	46	149
Average number of buildings in the neighborhood of LEED and/or Energy Star certified office buildings	439	536	515	521

Statistical Approach Method Analysis

The statistical approach applied for this research was conducted based on the results of the geographical analysis. The numerical data set for the statistical analysis was created by exporting the integrated information from the geographical approach. R-Project 3.0.2 was utilized for the overall statistical analysis, and the results of statistical approaches consisted of both a descriptive analysis and a regression analysis, described in turn below.

Descriptive Analysis

The descriptive analysis was to determine the number of LEED and/or Energy Star certified office buildings with each level of LEED certification coverage and its LEED certification level in Manhattan NYC from 2007 through 2013. Changes in the characteristics of LEED certified office buildings over time were shown in Table VI, VII, and Figure XXIII. The data in Figure III indicated that three of the six LEED certified office buildings have upgraded their LEED certifications from covering only part of the building to LEED certification for the whole building by the end of this research period; moreover, coincidently, those buildings adding new LEED certification for the whole building also achieved Energy Star certification before upgrading the LEED certification coverage of their certified office buildings. The remaining three LEED certified office buildings achieved only LEED certification for part of those buildings. The changes in LEED certification levels with the percentage of each LEED certification level in Figure XXIV. From 2007 through 2010, the proportions of the lower two levels of LEED certification, Certified and Silver, were at least 69 percent in all office buildings with LEED certification, and the Certified level was the only LEED certification level for 2007 and 2008. Over time, the proportion of the two lower levels steadily decreased with an increase in buildings receiving higher levels of certifications, although this trend showed signs of reversing near the end of the research period. In particular, the number of building achieved the Platinum level of

LEED certification rose from 0 to 2 during this study period. However, the numbers were very low to utilize the regression analysis for the buildings certified at the LEED Platinum level.

TABLE VI. CHANGES IN LEED CERTIFICATION COVERAGE OVER TIME

Change of LEED certification coverage	2007	2008	2009	2010	2011	2012	2013
Achieving LEED certification for part of the building	0	0	1	4	4	3	3
Adding additional LEED certification for the whole building for a building that was previously LEED certified for only part of building	0	0	0	0	1	1	1
Achieving LEED certification for the whole building	1	1	11	22	36	44	57

TABLE VII. CHANGES IN LEED CERTIFICATION LEVEL OVER TIME

LEED certification level	2007	2008	2009	2010	2011	2012	2013
Certified	1	1	1	8	9	10	13
Silver	0	0	8	10	15	17	23
Gold	0	0	3	7	14	18	22
Platinum	0	0	0	1	2	2	2
Total	1	1	12	26	40	47	60

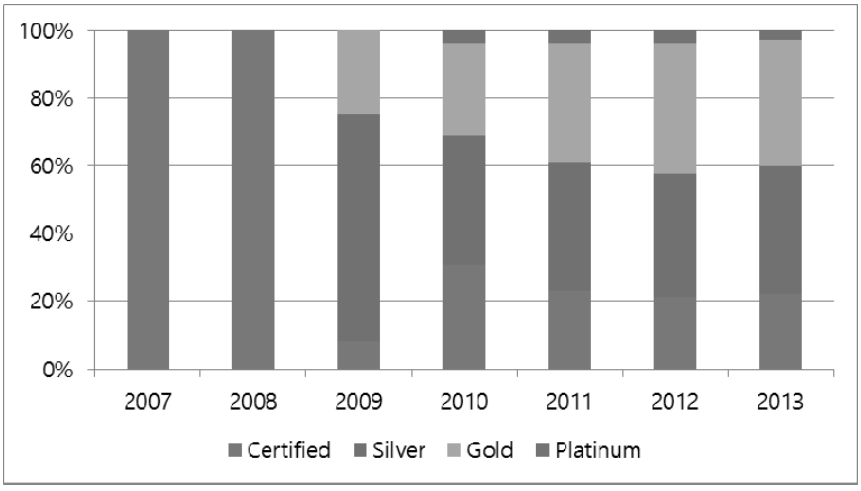

FIGURE XXIII. PROPORTION OF LEED CERTIFICATION LEVELS IN THE SAMPLE GROUP

In addition, the changes in the median unit market values of the 149 LEED and/or Energy Star certified office buildings during the research period are shown in Table VIII. Interestingly, there was no building with both LEED and Energy Star certification among the research sample in either 2007 or 2008, and the median unit market values after achieving LEED and/or Energy Star certification were higher than those prior to achieving certification. In addition, the median unit market value of LEED only certified office buildings in 2007 was lower than that of LEED only certified office buildings in 2013 after steadily increasing their value since 2008; the median unit

market value of LEED only certified office buildings increased every year between 2007 and 2013 except for 2008, when the fall coincided with a significant economic collapse in the U.S. In contrast, the first years of office buildings achieving Energy Star certification, 2007 and 2009, indicated the highest unit market values of certified buildings during the research period. Table VIII also indicated that the median unit market value of LEED and/or Energy Star certified office buildings kept up a slow but steadily increasing pace throughout the study period. The graph shown in Figure XXIV indicated that the median value of LEED and/or Energy Star certified office building and the mean value of those buildings underwent a similar transition from 2007 through 2013, with both values increasing steadily throughout the research period.

TABLE VIII. MEDIAN UNIT MARKET VALUES OF LEED AND/OR ENERGY STAR CERTIFIED OFFICE BUILDINGS ($/sq-ft)

Year	LEED certification only	Energy Star certification only	LEED & Energy Star certifications	Prior to achieving LEED and/or Energy Star certification
2007	209.4	289.2	NA	156
2008	176.2	253.3	NA	161.2
2009	215.6	219.8	289.5	157.3
2010	224.6	195.5	249.7	160.2
2011	280.5	178.8	236.7	158
2012	292.6	193.6	239.4	168.3
2013	284.7	196	269.6	189.6

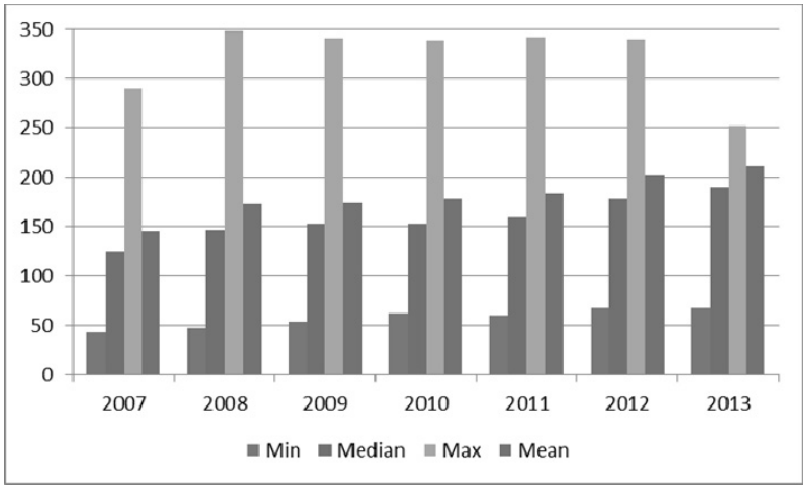

FIGURE XXIV. TRENDS IN NEIGHBORHOOD MEDIAN UNIT MARKET VALUES ($/sq-ft) FROM 2007 THROUGH 2013

Changes in the number of LEED and/or Energy Star certified office buildings are shown in Figure XXV and Table IX. Figure XXV illustrates how the number of LEED and/or Energy Star certified office buildings in Manhattan NYC has grown since 2007. However, although the number of LEED only certified office building has increased steadily, it was interesting that the numbers of both certified office building, Energy Star only and LEED and Energy Star, decreased in 2013. Buildings with Energy Star certification are required to re-evaluate their performance based on the actual building performance data during the certified year in order to renew their Energy

Star certifications for another year. In 2013, the number of Energy Star certification renewals for office buildings achieving Energy Star certification decreased by 66 compared with the number recertifying in 2012. The resulting decrease in the number of Energy Star certification was greater than the number of newly achieving Energy Star certification for both groups of certified office buildings in 2013. In Table IX, the number of lapsed Energy Star certifications increased steeply from 16 to 55 in 2013, but the number of renewed and new Energy Star certifications decreased or was maintained from 35 to 23 and from 43 to 43, respectively. It is hard to determine the specific reasons for this failure to renew Energy Star certification in 2013 because the data providers did not include this information, but it was likely due to the following three reasons: 1) a change in the requirements of Energy Star certification in 2012; 2) a change in building stakeholders' willingness to engage in and overall satisfaction with Energy Star certification; and 3) the disqualification of the actual building performance data for failing to satisfy the new Energy Star certification criteria introduced in 2012.

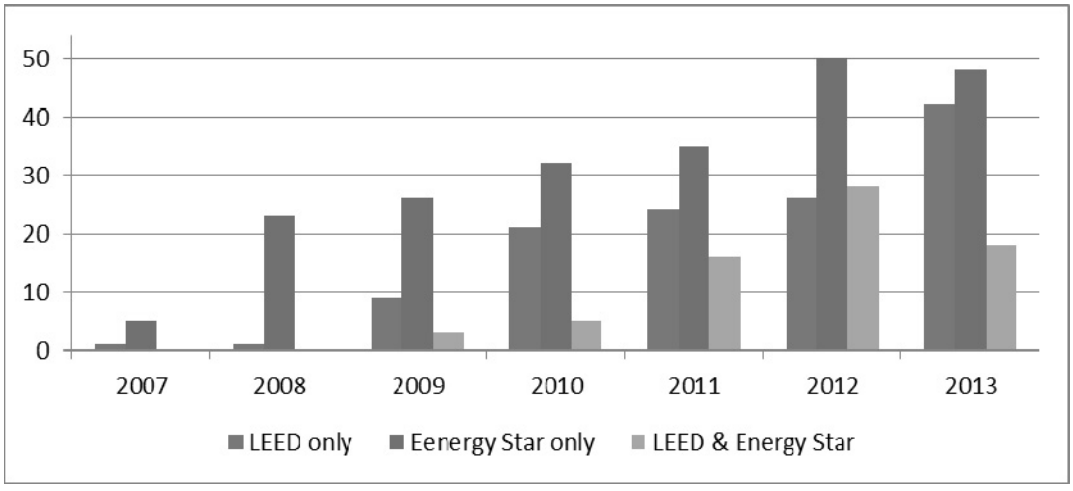

FIGURE XXV. NUMBER OF LEED AND/OR ENERGY STAR CERTIFIED OFFICE BUILDING IN MANHATTAN NYC

TABLE IX. THE NUMBER OF OFFICE BUILDINGS ACHIEVING ENERGY STAR CERTIFICATION (2007-2013)

	2007	2008	2009	2010	2011	2012	2013
No. of Energy Star certification	5	23	29	37	51	78	66
No. of renewed Energy Star certification	N/A	5	11	18	25	35	23
No. of new Energy Star certification	N/A	18	18	19	26	43	43
No. of lapsed Energy Star certification	N/A	0	12	11	12	16	55

Regression Analysis

The unit market value of a LEED and/or Energy Star certified office building and the median unit market value of other buildings in the neighborhood of a LEED and/or Energy Star certified office building had a correlation with a specific pattern, and the pattern of correlation is needed to comprehend for the appropriate regression methods.

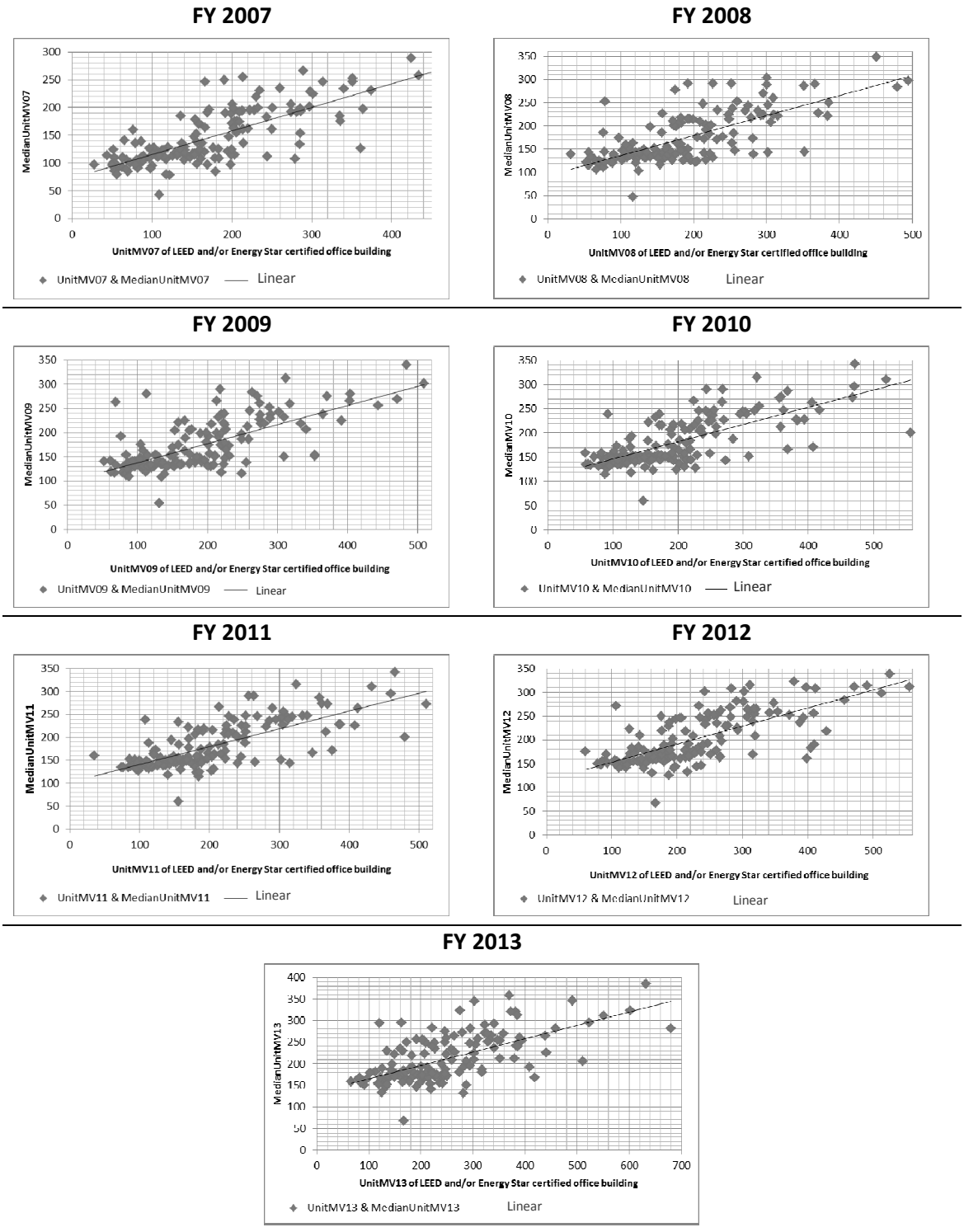

FIGURE XXVI. LINEAR CORRELATION BETWEEN TWO VARIABLES OVER TIME

Therefore, the pattern between these two variables was analyzed based on the distribution of points, and the results indicated that the correlation of the two variables had a linear correlation, as shown in Figure XXVI.

Fundamentally, the correlation between the unit market value of a LEED and/or Energy Star certified office

building and the median unit market value in its immediate neighborhood had the highest correlation value, 0.72, when the linear hedonic price model equation was applied for this model, as opposed to other hedonic price model equations. The R^2 value of the linear hedonic price model equation, 0.5319, was higher than the rest of R^2 values produced by any of the other hedonic price model equations throughout the research period. The results of the R^2 value for each of the four hedonic price model equations for 2011 as an example in Table X.

TABLE X. R^2 VALUE OF HEDONIC PRICE MODEL EQUATIONS FOR 2011

Transformation	Linear	Log-linear	Semi-log	Log-log
R^2 value	0.5319	0.489	0.4761	0.4486
Adjusted R^2 value	0.5222	0.4784	0.4653	0.4372

The further regression to determine the correlation between LEED and/or Energy Star certified office buildings and the median unit market value of buildings in their neighborhoods utilized the linear hedonic price model equation without any further data transformation, and the fundamental hedonic price model equation could be presented as below.

Median unit market value of buildings in the neighborhood = Unit market value of LEED and/or Energy Star certified office bldg. + LEED certification achievement + LEED certification coverage + LEED certification level + Energy Star certification achievement

Several linear mixed effect model analyses that incorporated top-down processes could be deployed to comprehend the effect of LEED and/or Energy Star certified office buildings on the median unit market value in their neighborhood as the below three steps.

Linear mixed effect model for achieving LEED and/or Energy Star certification

The linear mixed effect model for achieving LEED and/or Energy Star certification was utilized to analyze the effect of achieving these certifications on the median unit market value of buildings in the neighborhood, particularly the strength and the direction of the impact of both LEED and Energy Star certified office building. Therefore, basically, the equation for this analysis took the following form:

Median unit market value of buildings in the neighborhood = Unit market value of LEED and/or Energy Star certified office building + LEED certification achievement + Energy Star certification achievement

The results for this analysis model revealed that all the independent variables in this model were significant as all the p-values were lower than 0.05. Moreover, all the independent variables had a positive impact on the dependent

variable; the LEED certification had a much higher impact than the other three independent variables in Table XI, and the linear mixed effect model equation for this analysis model could be represented as follows:

Median unit market value of buildings in the neighborhood = 114.3217 + 0.3105 × Unit market value of LEED and/or Energy Star certified office building + 20.7178 × (LEED certification achievement) + 6.9597 × (Energy Star certification achievement) + α_0 + $\alpha_1 b$[6)]

TABLE XI. RESULTS OF THE LINEAR MIXED EFFECT MODEL FOR ACHIEVING LEED AND/OR ENERGY STAR CERTIFICATION

	Estimated coefficient	P-value
Intercept	114.32171	< 0.0001
Unit market value of LEED and/or Energy Star certified office building	0.31050	< 0.0001
Energy Star certification achievement	6.95967	< 0.0001
LEED certification achievement	20.71784	< 0.0001

Linear mixed effect model for the LEED certification level

The numerical value of the LEED certification level ranged from 1 for the Certified level through 4 for the Platinum level. Thus, this model analyzed the correlation between the four different levels of LEED certification and the median unit market value in the neighborhood. The response variable was the median unit market value in the neighborhood and the explanatory variables were the unit market value of the LEED and/or Energy Star certified office building and the LEED certification level. The model equation was shown below, and the result of linear mixed effect model analysis was in Table XII.

Median unit market value of buildings in the neighborhood = Unit market value of LEED and/or Energy Star certified office building + LEED certification levels

TABLE XII. RESULTS OF THE LINEAR MIXED EFFECT MODEL FOR THE LEED CERTIFICATION LEVEL

	Estimated coefficient	P-value
Intercept	111.52031	< 0.0001
Unit market value of LEED and/or Energy Star certified office building	0.33290	< 0.0001
Certified level	16.83060	< 0.0001
Silver level	22.76953	< 0.0001
Gold level	23.66242	< 0.0001
Platinum level	-39.88401	< 0.0001

The results indicated that all levels of LEED certification were significant because all the p-values for the

6) Where α_0 and α_1 are the estimated coefficients for the random effect of individual certified building.

independent variables were lower than 0.05. Furthermore, the result for the Platinum level of LEED certification had the only negative value among all the independent variables; the Platinum level of LEED only or LEED and Energy Star certified office buildings had a negative impact on the median unit market value in the surrounding neighborhood. This contrasted sharply with the findings for all the other levels of office buildings which achieved LEED certification. The linear mixed effect model equation for this model was as follows:

Median unit market value of buildings in the neighborhood = 111.5203 + 0.3329 × Unit market value of LEED only or LEED and Energy Star certified office building + 16.8306 × (LEED Certified level) + 22.7695 × (LEED Silver level) + 23.6624 × (LEED Gold level) − 39.8840 × (LEED Platinum level) + α_0 + $\alpha_1 b$[7]

Linear mixed effect model for the LEED certification coverage

The linear mixed effect model was applied to the LEED certification coverage and the achievement of LEED certification for the whole building or part of the building in order to analyze the correlation between the LEED certification coverage and the median unit market value of buildings in the neighborhood. The model equation was expressed as follows:

Median unit market value of buildings in the neighborhood = Unit market value of LEED and/or Energy Star certified office building + LEED certification coverages

The value for the LEED certification coverage was measured by assigning numerical values from 0 to 2, with no LEED certification being 0, LEED certification for part of the building 1, and LEED certification for the whole building 2, because the measurement of this variable was categorical data. Therefore, the numerical value of no LEED certification played a role as a reference against the remaining numerical values for LEED certification coverage, signifying LEED certification for part or whole of the building. The results for this model indicated that all the independent variables were significant, and the result indicated that all the independent variables had a positive impact on the median unit market value of buildings in the neighborhood. The LEED certification for the whole building had a more powerful impact on the dependent variable than the certification for part of the certified building and the detail results are in Table XIII, and the linear mixed effect model equation is expressed as below.

TABLE XIII. RESULTS OF THE LINEAR MIXED EFFECT MODEL FOR THE LEED CERTIFICATION COVERAGE

	Estimated coefficient	P-value
Intercept	115.46278	< 0.0001
Unit market value of LEED and/or Energy Star certified office building	0.31311	< 0.0001
LEED certification for part of the building	15.32934	0.0162
LEED certification for the whole building	21.08269	< 0.0001

7) Where α_0 and α_1 are the estimated coefficients for the random effect of individual certified building.

Median unit market value of buildings in the neighborhood = 115.4628 + 0.3131 × Unit market value of LEED certified office building + 21.0827 × (LEED certification for the whole building) + 15.3293 × (LEED certification for part of the building) + α_0 + $\alpha_1 b$[8]

Model Validation

To validate the above three numerical models, this research utilized the Log-likelihood Ratio Test (LRT) which compared the fitted model with the null model and indicated the fitness of the fitted model through the numerical results. These numerical models included the intercept and random effects for the performance of LRT; the null model was that the fitness of the fitted model is decreased by adding more variables to the fitted model. Moreover, the hypotheses for LRT were as follows:

H_0: The null model is true. vs. H_1: The null model is not true.

All results of LRT were 783.6022, 757.26, and 680.4387 and the p-values for three linear mixed effect models indicated that the values were significant because they were smaller than 0.0001. The values of AIC (Akaike Information Criterion) and BIC (Bayesian Information Criterion) for the fitted models were smaller than the values of both criteria for the null model, indicating that H0 was rejected and the fitted models were statistically more significant than the null model.

DISCUSSIONS AND CONCLUSION

The purpose of this research was to measure the effect of LEED and/or Energy Star certified office buildings on their neighborhoods to encourage the mutual benefits for both the LEED and/or Energy Star certified office buildings and other buildings in their neighborhoods for the economic revitalization of local real estate market by examining the median unit market values of buildings in the neighborhood surrounding a certified building in Manhattan, NYC. The results demonstrated that in terms of the unit market value of buildings in the neighborhood, the changes in the unit market value of a LEED and/or Energy Star certified office building that occurred through achieving LEED and/or Energy Star certification and the supplemental building characteristics added by the features of LEED certification indeed have a positive impact on the neighborhood except for the Platinum level of LEED certification, which presented a negative impact due to the limited number of LEED Platinum certified office buildings in the sample. The strengths of the positive impact of unit market value of LEED and/or Energy Star certified office buildings were very similar, a relatively lower value than other independent variables. The achievement of LEED and/or Energy Star certification also generally provided a positive boost for neighborhood unit market values. These results demonstrated that LEED certification had a more positive impact on

8) Where α_0 and α_1 are the estimated coefficients for the random effect of individual certified building.

neighborhood's median unit market value than Energy Star certification and that every LEED certification level except for the Platinum level and all LEED coverages had a positive impact on median unit market values for their neighborhood. In future studies, more research is required to verify the coefficient value for LEED Platinum certified office buildings by including a sufficient number of LEED Platinum certified office buildings. Moreover, further work will be needed to analyze the correlation between proximity to a LEED and/or Energy Star certified office building for each individual building located within a specific radius neighborhood area. These findings indicate that within this data set of LEED and/or Energy Star certification may offer an effective economic impact on the unit market values of buildings in the neighborhood, within 0.25 miles, in Manhattan NYC. In addition, the LEED and/or Energy Star certification provided economic benefits to not only the certified building stakeholders but also their neighbors and communities. These results confirm that LEED and/or Energy Star certification does indeed play a useful role in contributing to the economic vitality of its neighborhood and thus a part of the triple bottom line of sustainability for LEED and Energy Star certifications as well as their surrounding neighborhoods. By sharing their economic benefits with their neighbors and local communities, the building stakeholders of LEED and/or Energy Star certified office buildings could also help improve and revitalize their local real estate market economically.

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