The Spillover Effect of Proximity to LEED-Energy Star Certified Office Buildings on Neighborhood Market Values

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ABSTRACT

The construction industry's two main certifications are Leadership in Energy and Environmental Design (LEED) and Energy Star. To achieve the triple bottom line of sustainability for these certifications, both certifications should make a positive impact individually as well as mutually, with their impact extending to the surrounding neighborhood. This research examined the spillover effect of LEED and/or Energy Star certified office buildings on the property values of other buildings in their neighborhood in Manhattan, New York City from an economic standpoint. The spatial analysis approach using the Geographic Information System and the statistical analysis approach based on the Hedonic Price Model and the Linear Mixed Effect Model were applied to identify the geographical distribution of LEED and/or Energy Star certified office buildings and their other buildings in their neighborhoods and analyze the impact of the former on the latter. The results were as follows: 1) There was a significant correlation between a LEED and/or Energy Star certified office building and the unit market values of its adjoining buildings through the unit market values of the certified office building, the LEED and/or Energy Star certification achievement, and the major features of LEED certification; 2) There was a varying spillover effect of the certified office building on the median unit market value of buildings depending on their proximities to a LEED and/or Energy Star certified office building. This research provides a firm foundation for further efforts to quantify the spillover effect of LEED and/or Energy Star certification on a neighborhood from an economic standpoint, thus supporting and encouraging growth in the local real estate market and benefitting not only the owners, developers, and investors of the certified office building but also the owners of neighboring buildings.

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Last, but not least, I would like to express my heartfelt gratitude to my beloved family, Kahyun Yoo and Ethan J. Suh, and to dedicate this dissertation to my whole family, including those people living in South Korea. There is no doubt that I could not have completed my academic journey successfully without their dedicated support, devotion, effort, and prayers. Thank you all.

ATTRIBUTION

The research conducted for this dissertation examined the question of whether green building certifications do indeed contribute to efforts to attain sustainability goals. Can the concept of green building certifications, with its narrow focus on the environmental aspects of constructing and operating a building, be extended to encompass the economic benefits provided to the surrounding buildings and neighborhoods? This dissertation consists of four self-contained chapters that have all been published in, or prepared for an immediate submission for publication in peer-reviewed conferences or journals. This attribution statement introduces the co-authors and clarifies their contributions to the work reported in each chapter. In every chapter, the core ideas, primary contributions, primary data collection, major decisions on data analyses and significant data analyses, and interpretation of the results related to the overall objectives of this dissertation were executed by the Ph.D. candidate, Min Jae Suh. The contributions of most of the co-authors consisted primarily of reviewing each chapter and providing suggestions and guidelines for revisions. The specific contributions of the co-authors for each chapter are described below.

Chapter 2: Min Jae Suh prepared and conducted the research reported in this chapter by developing the core concept, reviewing the relevant literature, collecting and analyzing the primary data, interpreting the statistical results, and revising the paper. Annie R. Pearce suggested the research scope and framework for this research, reviewed the resulting paper, and provided useful suggestions for revision. Young Hoon Kwak helped to select the appropriate data source for the statistical analysis and then reviewed the final paper.

Chapter 3: Min Jae Suh developed the fundamental concept and the framework of this paper, as well as conducting the literature review and being responsible for the data collection and geographical analysis, and the interpretation of the results. Annie R. Pearce suggested the research scope of the research and the framework of this paper, as well as conducting a critical review and making valuable suggestions for revision. Yuhyun Song provided useful suggestions for developing the statistical analysis method utilized in the study, the Linear Mixed Method, and reviewed the results section to ensure the quality of the interpretation presented in the paper. Young Hoon Kwak helped to select the appropriate data source for the statistical analysis and then reviewed the final paper. Yang Zhang helped to create and develop the GIS mapping of the research area. Kimberly J. Mitchell and Flynn Auchey reviewed and provided valuable suggestions and comments for revising the paper.

Chapter 4: In addition to preparing the paper, Min Jae Suh developed the fundamental concept and the framework for this research, and conducted a literature review, data collection and geographical analysis, and interpretation of the results. Moreover, Min Jae Suh suggested the utility of adopting the statistical analysis method (Linear Mixed Effect Method) applied and reviewed the results to ensure the quality of interpretation in this paper. Annie R. Pearce suggested the research scope of this dissertation and the framework of these papers, and conducted a critical review with the suggestions for revision. Yang Zhang helped to develop the GIS mapping for this research. Kimberly J. Mitchell and Flynn Auchey provided several suggestions for developing and refining this research.

Chapter 5: Min Jae Suh developed the key concept and the framework of this paper, and conducted a literature review, data collection and analysis, and interpretation of the results. As in the three previous papers, Annie R. Pearce suggested the research scope and guided the development of the framework of this study, and conducted a critical review of the resulting paper, with suggestions for revision. Kimberly J. Mitchell and Flynn Auchey provided several suggestions for developing and refining this research. Lastly, Yang Zhang helped to interpret the results of the GIS mapping.

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CHAPTER 1

Introduction

The increasing emphasis on sustainability in all aspects of our daily lives is no longer limited to researchers in fields such as the humanities, economics, and social sciences but is also attracting interest from those in engineering and environmental science. This has added to the pressure on construction professionals to explore the wide range of options that are being developed to support sustainable construction practices. Of particular relevance are the efforts of environmental bodies in developed countries to find ways to measure sustainability of buildings through systematic assessment and assign levels according to one of the developed green building rating systems.

In the United States, the two leading green building certifications are Leadership in Environmental and Energy Design (LEED) and Energy Star, both of which are utilized in the construction industry. The interest in and number of these certifications around the world has also increased steadily, and the U.S. Green Building Council (USGBC) is currently establishing and operating the LEED International Roundtable, which consists of 34 countries at the time of writing, 2014, to support LEED certification internationally as a green building powerhouse.

As a result of this growing interest and the increasing number of LEED and Energy Star certified buildings, numerous researchers have studied the impact of LEED and/or Energy Star certification on various aspects of our communities, looking at a wide range of research topics and adopting various approaches. A number of studies have demonstrated the impact of LEED and/or Energy Star certification on the property values of the LEED and/or Energy Star certified buildings, and have found that LEED and/or Energy Star certification generally had a positive impact on the certified building from an economic standpoint, either directly or indirectly. At the same time, these studies have rarely addressed the need for research into the impact of LEED and/or Energy Star certification on the property values of the other buildings in the surrounding neighborhood. An overall statistical picture of the economic impact of LEED and/or Energy Star certified buildings on the property values of buildings in their neighborhood would thus be helpful, providing a more comprehensive picture of the contribution to local real estate markets and communities as an element of the sustainability of green building certification via the LEED and Energy Star certifications. The research reported in this dissertation used a spatial analysis approach to integrate detailed geographic information on LEED and/or Energy Star certified office buildings and buildings in their neighborhoods and determine functional definitions of adjoining building, neighborhood and sub-neighborhood. In addition, statistical analysis approaches were applied to identify correlations between a LEED and/or Energy Star certified office building and its adjoining buildings, neighborhoods, and five sub-neighborhoods from an economic standpoint.

This research was based on the conjecture that the LEED and/or Energy Star certifications are indeed among the socio-environmental factors that have a significant impact on the property values of surrounding buildings in their neighborhoods, in this case by serving as an external feature in the existing environment. Moreover, the scope of this research should be fundamental in nature if it is to fully explore a new way of expanding the concept of “green” beyond simple environmental performance to include critical economic factors related to green building certifications that take into account not only the notions of energy efficiency and environmentalism, but also the economic performance of the certified buildings and buildings in their surrounding neighborhoods, win-win strategies that benefit both local real estate markets and local communities.

Problem Statement

In theory, the property value of a building is appraised based on both its internal features and external features in its existing environment. The particular internal features of an individual building can also play a role as a significant external feature in the existing environment of neighboring buildings in a real estate appraisal (Epley and Rabianski 1981; Bloom et al. 1984; Epley et al. 2002). Moreover, the different impact of external features in the existing environment on the property values of buildings in a neighborhood depending on a building’s proximity to those features has been clearly demonstrated in previous studies[1] focusing on the spillover effect of external features in the existing environment. This research into the spillover effect on the local neighborhood area examined the impact of external features such as the unit market value of the LEED and/or Energy Star certified office building, the achievement of LEED and/or Energy Star certification, and the specific characteristics of LEED certification on the existing environment in its neighborhood from an economic standpoint.

Accordingly, the research question examined raised the possibility of the potential spillover effects of LEED and/or Energy Star certified office buildings on their neighborhood property values as a function of the different proximities between the certified office building and buildings located within the same neighborhood. LEED and/or Energy Star certification might be a private or independent feature in the existing environment surrounding a building in the same way as a characteristic like a foreclosure had a negative impact on property values in the surrounding neighborhood, although in this case it was hypothesized to deliver a property value benefit to buildings in the neighborhood area around the LEED and/or Energy Star certified office buildings due to the positive economic impact of LEED and/or Energy Star certification on the property value of certified office buildings. Various strengths of spillover effects from three different types of certified office buildings, namely, achieving only LEED certification, only Energy Star certification, or both the LEED and Energy Star certifications, were therefore investigated based on the proximity between the certified office building and individual buildings in its immediate neighborhood. The certifications were expected to exert various strengths of the spillover effect on market values in the neighborhood, depending on how close each building and each neighborhood were to the certified building.

Increasing the property value of buildings in a neighborhood has benefits not only for the people who own those buildings, but also for the local real estate market and local community. Hence, this dissertation defines ‘increase in the market value of a building’ as an economic benefit to the certified office building owners and people associated with the certified office building; moreover, this study explores the economic benefits provided by

[1] Table 5.1 in Chapter 5.

a LEED and/or Energy Star certified office building in terms of their ability to support an element of the sustainability of these certifications by providing evidence that they indeed contribute to satisfying the economic aspect of the triple bottom line of sustainability for the LEED and Energy Star certifications: Environmental, Economic, and Social[2].

As a result, this research was designed to measure the economic benefits to the surrounding neighborhood areas conveyed by LEED and/or Energy Star certified office buildings as a function of market value, and to examine more closely the meaning of sustainability in the context of LEED and/or Energy Star certification.

Objectives

The major objectives of this dissertation research were: (1) to determine the geographical definition of the neighborhood and sub-neighborhood areas of LEED and/or Energy Star certified office buildings to facilitate the measurement of the spillover effect of LEED and/or Energy Star certification and (2) to establish numerical equations using statistical modeling approaches to analyze the correlation between the attributes of a LEED and/or Energy Star certified office building and other buildings in its neighborhood area, using a market value data set provided by a government agency.

Additional objectives of this research were:

- To define key terminologies: certified building, office building, adjoining building, neighborhood areas, proximity radius, unit market value, median unit market value, walking distance, New York City;
- To identify and classify LEED and/or Energy Star certified office buildings;
- To classify nearby buildings as being adjoining buildings or part of the neighborhood areas;
- To identify the characteristics of buildings in the same neighborhood;

[2] Freer Spreckley (1981). "Social Audit: A Management Tool for Co-operative Working 1981."

- To determine the correlation between the unit market value of buildings in the same neighborhood or the median unit market value of sub-neighborhood areas surrounding LEED and/or Energy Star certified office buildings and the unit market value of LEED and/or Energy Star certified office buildings in Manhattan, New York City; and

- To identify any correlations between changes in the unit market values of certified office buildings and buildings in their neighborhood area and their sub-neighborhood area based on their proximity to the certified building by measuring trends in the median unit market values of buildings in the same neighborhood or sub-neighborhood.

Research Approach

The research approach for this research consisted of identifying and determining data related to the objectives outlined in the research questions guiding this research. The overall objectives were investigated by the following tasks:

1. Literature review: An extensive literature review was conducted in order to gather as much information as possible regarding past and present research into the various topics that were immediately related to the keywords of this dissertation, namely sustainability, LEED certification, Energy Star certification, spillover effect, market value, neighborhood, hedonic price model, linear mixed effect model, and Geographic Information System (GIS). Numerous literature reports dealing with topics that covered the key terminologies of this dissertation from various theoretical or practical research standpoints were identified. The literature review served as a useful way to establish the specific definitions of the terminologies utilized for this dissertation, taking into consideration the multiple conditions these topics included. However, no reports were found of studies examining the spillover effect of LEED and/or Energy Star certification from either an economic standpoint of the type needed to address the triple bottom line of

sustainability for these certifications.[3] Instead, most previous studies focused primarily on constructing various types of infrastructure facilities or changing economic conditions at either the macro-scale or micro-scale. In spite of the lack of information on the spillover effect of features associated with LEED and/or Energy Star certification, it was reasonable to expect a LEED and/or Energy Star certified office building to be one of the features in existing environments that had an effect on surrounding buildings from the economic standpoint. Moreover, any changes in the property values of LEED and/or Energy Star certified office buildings due to the achievement of LEED and/or Energy Star certification were also likely to have an economic impact on the property values of buildings in the surrounding neighborhood. Therefore, a LEED and/or Energy Star certified office building could be an appropriate starting point from which to examine the resulting spillover effect of LEED and/or Energy Star certified office building on the property values of buildings in its neighborhood.

2. Data collection and reproduction: Various primary data sets were required to carry out the statistical analysis for this dissertation. These data sets were provided by several different organizations, all of which employed different styles or types of primary data. Therefore, it was necessary to extract the necessary information from the primary data sets and reformat the data to make it compatible with the statistical methods utilized for this research in terms of the secondary data sets.

3. Geographical analysis method: It was important to pinpoint the precise geographic information of each of the LEED and/or Energy Star certified office buildings and adjoining buildings or buildings in their neighborhoods for this dissertation. The numerical data sets from several organizations were imported into the GIS, including ArcGIS 10.1, and the data were transformed into an appropriate visualization to facilitate the depiction of trends in the data on a different type of map for each neighborhood. The ArcGIS 10.1 tool supported the geographical analysis by determining the group of adjoining buildings based on the geographical location of individual LEED and/or Energy Star certified office buildings and their neighborhood areas based on the radius

[3] Table 5.1 in Chapter 5.

from the centroid of the geographical location of the certified office building, verifying a few determinations visually, and constructing and exporting an integrated data sheet containing the required information of all the buildings for the statistical analysis approaches.

4. Statistical analysis method: The spillover effect was measured by examining the correlation between the unit market value of each LEED and/or Energy Star certified office building and the unit market values of adjoining buildings or the median unit market values of buildings in the neighborhoods and sub-neighborhoods using two statistical analysis models: the hedonic price model and the linear mixed effect model. Both models were based on numerical data, and both provided the significance for each correlation measured between a dependent variable and independent variables, as well as the direction, namely the positive or negative impact, of the correlation between each pair of independent and dependent variables. The hedonic price model was utilized for the measurements of social capital or the value of the environment based on cross sectional data for property values, and was also applied for measuring the neighborhood effect that occurred due to the characteristics of the economic and physical make-up of the area. However, the hedonic price model was less useful for analyzing the longitudinal data because the model focuses on a specific point in time. In this research, the hedonic price model was utilized to determine the natural logarithmic transformation of the values of the data sets performed to obtain improved R^2 values. The linear mixed effect model was generally employed as it provided a useful way to analyze both the cross-sectional data and the longitudinal data; moreover, this model was utilized to quantify the significance of the correlations between independent variables and dependent variable and the strength of the impact of each independent variable on the dependent variable through the statistical results in this dissertation.

5. Comparison of the strength of spillover effect of LEED and/or Energy Star certified office building: It was essential for the strength of the spillover effect on the adjoining buildings and neighborhoods surrounding each of the LEED and/or Energy Star certified office buildings to be supported by a rigorous statistical analysis. The coefficient values of the independent variables reported in this dissertation therefore indicated the

strength of the spillover effect based on each building's proximity to a LEED and/or Energy Star certified office building, as well as the variations in the strength of the spillover effect of each LEED and/or Energy Star certified office building was considered based on five incrementally decreasing proximities to that LEED and/or Energy Star certified office building.

6. Recommendations for supporting the sustainability of LEED and/or Energy Star certification: The purpose of this dissertation was to define the sustainability of LEED and/or Energy Star certification in terms of the economic effect of LEED and/or Energy Star certified office buildings on their adjoining buildings and neighborhood areas based on five different proximities to the certified office building. The recommendations of this dissertation describe the current status of the sustainability of LEED and/or Energy Star certification from an economic standpoint and suggest the necessity for improving our understanding of the sustainability for LEED and/or Energy Star certification by conducting further research in this area.

Dissertation Organization

This dissertation consists of one conference paper and three journal articles grouped under a single research theme, with individual manuscripts being presented as individual chapters. There is, therefore, inevitably some repetition among the introductory sections and background information in these four chapters because each was written as a self-contained paper.

Chapter 1: *Introduction* – The introductory section of this dissertation consists of the problem statement, objectives, research approach, and dissertation organization.

Chapter 2: *The Effect of LEED Certified Building on the Surrounding Neighborhood in New York City* – This conference paper demonstrated how the enhanced real estate value of LEED certified buildings in New York City does indeed extend to adjoining commercial buildings by identifying the correlation between the property value of each LEED certified building and that of its adjoining commercial buildings by looking at their market values, as part of the preliminary research carried out for this dissertation. The results presented in this paper showed that one of the leading green building certifications, Energy Star, could also benefit from a deeper study of the economic benefits to neighboring buildings in further research. This conference paper was presented and published in *The Proceedings of the Fifth International Conference on Construction Engineering and Project Management* (Anaheim, CA, USA, January 9-11, 2013).

Chapter 3: *The Impact of LEED-Energy Star Certified Office Building on the Market Value of Adjoining Buildings in New York City* – This journal paper will be submitted to the *Journal of Sustainable Real Estate* in 2015. The purpose of this research was to understand the effect of LEED and/or Energy Star certified office buildings in Manhattan, NYC on the unit market value of adjoining buildings from an economic standpoint. This study extended the work reported in Chapter 2, and included additional fundamental research to quantify the effect of LEED and/or Energy Star certified office buildings on their neighboring buildings, focusing specifically on the correlation between the features of LEED and/or Energy Star certified office building and the unit market values of their adjoining buildings over time using both spatial and statistical approaches, adopting an economic standpoint.

Chapter 4: *The Impact of LEED-Energy Star Certified Office Buildings on the Market Values of Neighboring Areas in New York City* – This manuscript will be submitted to the *Journal of International Real Estate and Construction Studies* in 2015. This research examined the effect of LEED and/or Energy Star certified office buildings on the median unit market value of buildings in their neighborhoods, based on the generally accepted definition of walkable distance. Spatial and statistical analyses revealed interesting differences between the impacts of LEED and/or Energy Star certification based on the correlation between specific features of each type of certification and the median unit market value of buildings in the neighborhood from an economic standpoint.

Chapter 5: *The Spillover Effect of Proximity to LEED-Energy Star Certified Office Buildings on Neighborhood Market Values in New York City* – This paper will be submitted to the *Journal of Green Building* in 2015. This research focused on conducting spatial and statistical analyses to identify the spillover effect of LEED and/or Energy Star certified office buildings in Manhattan, New York City, on the median unit market values of surrounding buildings in five distinct sub-neighborhoods by examining the impact of five different proximities between a LEED and/or Energy certified office building and each of the five sub-neighborhoods based on the median unit market value of the buildings in each sub-neighborhood. Based on the median unit market value for each sub-neighborhood centered on a LEED and/or Energy Star certified office building, the strength of this spillover effect due to the LEED and/or Energy Star certified office building revealed by the correlations between the features of the LEED and/or Energy Star certified office building and the median unit market value of buildings in each sub-neighborhood were indeed found to depend on a building's proximity to the certified office building, but the spillover effect of the certified office buildings indicated a positive direction for all five of the different sub-neighborhoods, regardless of the proximity to the certified office building of each.

Chapter 6: *Conclusions and Recommendations* – This chapter summarizes the overall research including the major findings, conclusions of each chapter, and contributions, and also suggests several recommendations for future research on the spillover effect of LEED and/or Energy Star certified office buildings.

Appendix A: *Glossary* – This appendix provides detailed definitions of key terms in this dissertation to prevent readers from misunderstanding potentially ambiguous meanings that may be associated with each term.

Appendix B: *Extended literature review* – This appendix provides additional specific information about the economic benefits of LEED and/or Energy Star certified office buildings. Furthermore, the characteristics of commuters living and/or working in Manhattan, New York City, and data on New York City Metropolitan Transportation Authority (NYCMTA) subway ridership related to the determination of walkable distance in Manhattan, New York City, for this dissertation are explained in this appendix.

Significance

The major contributions made by this research consisted of the comprehensive analyses provided of the economic impacts of a LEED and/or Energy certified office building on other buildings in its neighborhood and changes in the spillover effect of the certified office building based on proximity to the certified office building. This extends previous studies, which have investigated the economic or environmental benefits of LEED or Energy Star certification only on the certified building itself using economic measurements of the property value such as rental rates, unit sales price, occupancy rate, and so on, or its operational and maintenance costs such as the monthly or annual energy bills and the amount of water consumption. The studies included in this dissertation represent the first attempt to evaluate the wider benefits due to LEED and/or Energy Star certification for their surrounding neighborhoods and their local communities and governments from an economic standpoint. In particular, the spillover effect of a LEED and/or Energy Star certified office building and its economic benefits for neighboring buildings with different proximities to the certified office building break new ground. The methodologies in this dissertation contributed to the measurement of the spillover effect on the local real estate market as a result of a building gaining LEED and/or Energy Star certification. These approaches are expected to contribute to future efforts to develop a predictive model that takes into account the potential spillover effect of these certifications for future building investors or owners. They are also expected to be useful when considering the revival and revitalization of local real estate markets by encouraging new construction or renovated building projects to aim for both LEED and Energy Star certification by local governments and communities seeking to support their local real estate market.

Chapter 2

The Effect of LEED Certified Building on the Surrounding Neighborhood in New York City

Min Jae Suh[1], Annie R. Pearce[2], and Young Hoon Kwak[3]

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Abstract: The construction industry has introduced the Leadership in Energy and Environmental Design (LEED) certification to promote objective evaluations of the sustainability of buildings. Three important values to consider when implementing sustainability were the associated environmental, social, and economic impacts. Recently, researchers have begun to investigate the real estate value of LEED certified buildings in terms of the rental rates, occupancy rate, cost per unit area, and resale value in order to better understand the economic benefits of the LEED certification. However, the economic benefits also encompass economic effects such as the impact of LEED certified buildings on neighborhood real estate values surrounding the certified buildings. This research examines whether the enhanced real estate value of LEED certified buildings in New York City extends to surrounding commercial buildings, utilizing spatial analysis via a Geographic Information System (GIS) and the hedonic pricing method to derive meaningful economic relationships. The results provide practical insights into the economic effect of LEED certified buildings that will be of interest to city officials and planners, as well as the owners, developers, investors and other stakeholders of

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surrounding buildings.

Introduction

The recent increased emphasis on sustainability has encouraged the construction industry to explore new ways to implement more sustainable construction practices. In particular, several advanced countries such as the United States, the United Kingdom, Japan, and Canada are attempting to measure the performance of green buildings through rigorous assessment by developing national green building rating systems. According to Pearce et al. (2012), a number of green building rating systems have been developed globally to examine and judge degree of capital project sustainability. These green building rating systems are expected to contribute to the detailed and specific understanding of sustainability by the stakeholders of the buildings.

The LEED certification proposed by the United States Green Building Council (USGBC) in 1995 took as its starting point the United Kingdom's Building Research Establishment Environmental Assessment Method (BREEAM) and extended it to cover different types of construction projects. The LEED certification is divided into six construction sectors and includes new construction, existing buildings, and commercial interiors. It also endeavors to cover a wide range of conditions of construction projects in a systematic manner (Pearce et al. 2012). In addition to the United States, 21 other countries, including France, India, Mexico and Korea, participate in the LEED International Program, supporting the USGBC's claim that the LEED certification of each of the participating countries represents "global consistency, a regional approach, and local outreach and support" (McAllister 2011). As a result, Booz Allen Hamilton Inc. (2009) mentioned that the number of LEED certified buildings is steadily increasing worldwide, with approximately just over 4 million cumulative certified square feet expected by the end of 2013. There are now sufficient LEED certified buildings that have been in operation for long enough periods that studies of the effectiveness of the LEED certification and its impacts are now viable, leading to an explosive growth in research in this area. Several researchers studied the impact on real estate values of LEED certified buildings, revealing that the real estate values of LEED certified buildings tend to rise after achieving the LEED certification (McGraw-Hill Construction 2008; Miller et al. 2008; Eichholtz et al. 2010; Fuerst and McAllister 2011). The real estate value is determined by the principle of supply and demand in a competitive market economy, but the real estate value of a building is also affected by two additional features: the real property commodity itself, namely the on-site characteristics of particular aspects of the property such as its physical features, aesthetic features, locational features and so on; and its surrounding environment, which consists of external characteristics that affect the property such as local economic factors, social factors, political factors and so on (Epley and Rabianski 1981; Epley et al. 2002). McGraw-Hill Construction (2008), Miller et al. (2008), Eichholtz et al. (2010), and Fuerst and McAllister (2011) concluded that the LEED certification was considered to be a feature of the real property commodity itself, and researchers found that LEED certified buildings had higher real estate values than would otherwise have been the case. The LEED certification could be likely to play a role in terms of the surrounding environment as well. It is therefore necessary to investigate the impact of the LEED rating system on real estate values in the surrounding neighborhood as part of research into the impact of LEED certified buildings on real estate values. Sustainability as a concept was being discussed long before the idea of a green building certification existed. The Organization for Economic Co-operation and Development (OECD) published a report on the concept of eco-efficiency entitled 'Our Common Future' in 1987, and the World Business Council for Sustainable Development (WBCSD) also emphasized the importance of eco-efficiency in their 1992 report 'Changing Course'. Since the concept of eco-efficiency was first introduced, McDonough and Braungart (2002) and Barbiroli (2006) have stressed the importance of including the concept of eco-effectiveness if true sustainability is to be achieved. Kerstens et al. (2001) and Lee (2004) suggested applying the principle of the '3Ps' for the implementation of sustainability. The '3Ps', shown in Figure 2.1, stands for 'People', 'Planet' and 'Profit'; 'People' represents social issues, including the provision of spaces that benefit those using them; 'Planet' stands for the environmental aspects, encompassing energy saving and the prevention of natural resource depletion for the protection of natural environment; and 'Profit' represents the economic benefits to be gained, signifying that buildings or infrastructure systems can return outcomes that are innovative and provide better values for their society or community in all aspects. Of these three aspects, this research focuses on ‘Profit’ by exploring the question of how the LEED certification provides concrete economic benefits for both the LEED certified buildings and those surrounding them. A number of different socio-environmental factors have an influence on the real estate values in a neighborhood area, and the LEED certification is hypothesized to be one of those socio-environmental factors that have a significant impact on real estate values in a surrounding neighborhood.

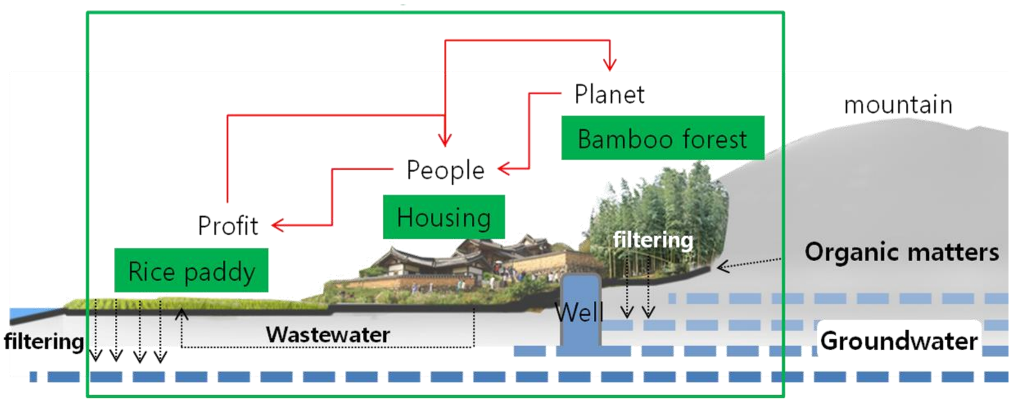

Figure 2.1. Principle of the 3Ps

Therefore, this research investigates the effect of LEED certified buildings on real estate values in their surrounding neighborhood; moreover, it proposes a new ideology for green building certifications that takes into account not only the notions of energy efficiency and environmentalism, but also the economy at the local level. The results of this research are expected to affect the diffusion of the LEED certification by encouraging building stakeholders, the neighborhood as a whole, and federal and local government to see the LEED certification from a fresh perspective. The benefits to each of the stakeholders are illustrated in Figure 2.2 below.

Figure 2.2. New Green Ideology by LEED Certification

Background

This research sought to integrate several research areas; therefore it was first necessary to connect the literature on each and determined which factors were relevant to this research of the impact on surrounding neighborhood real estate values of the LEED certified buildings within it.

Real Estate Values of LEED Certified Buildings

Even more than 10 years after the initial appearance of the LEED certification, researchers interested in the LEED certification continue to evaluate its impact in terms of added real estate value. McGraw-Hill (2008), Miller et al. (2008), Eichholtz et al. (2010), and Fuerst and McAllister (2011) have all conducted detailed examinations of the effect of the LEED certification on the assessed and market values of LEED certified buildings vs. non-certified buildings under similar conditions in detail. These studies consistently conclude that LEED certified buildings have a higher real estate value than non-certified buildings based on several economic variables utilized for building appraisals, namely rental rates, cost per unit area, occupancy rate, and resale value rate. Table 2.1 summarizes the results for four studies

Table 2.1. Comparisons of the Real Estate Value of LEED Certified Buildings and Non-Certified Buildings under Similar Conditions

	Rental rates		Cost per unit area (Price/sq-ft)		Occupancy rate (%)		Resale value rate	
	Certified	Non-certified	Certified	Non-certified	Certified	Non-certified	Certified	Non-certified
McGraw-Hill (2008)	103%	100%			100	96.5	1.075	1
Miller et al. (2008)	$42.15	$28.00			92.0	87.8	1.099	1
Eichholtz et al. (2010)	$29.84	$28.14	$289.22	$248.89	89.12	81.35	1.16	1
Fuerst & McAllister (2011)	$27.07	$24.68			88.5	86.06		

Note: All comparisons were chosen based on the locations of existing LEED certified buildings and were based on the unique external conditions for each case, including the geographic location, building size, building age, and period when the research was conducted.

The Impact on the Real Estate Value of a Building Due to Features in the Existing Environment

Real estate values are typically determined by the interaction between demand and supply in the real estate market (Epley and Rabianski 1981; O'Sullivan 2009). As stated earlier, the real estate value of a specific building is affected by the real property commodity itself and the features of the environment in which it exists. Environmental determinants of value can be classified in terms of the following: social factors, location factors, physical factors, economic factors, and government and political factors (Epley and Rabianski 1981; Epley et al. 2002; Bloom et al. 1984). Applying these environmental determinants, several researchers have studied the effect of environmental determinants of value on the real estate value of buildings. Hough and Kratz (1984), Weinberger (2001), Hui et al. (2007), and Chun et al. (2011) investigated economic changes in real estate values in areas which had undergone a neighborhood environmental change. Taking either residential properties or commercial properties as the dependent variables, in most cases the studies looked at changes in real estate values due to the addition of new large-scale infrastructure projects, such as airports, urban green areas, parks, and land use, and the associated changes in the surrounding environment, such as noise level, air quality, and prospect view, all of which are related to the quality of life. The three cases that took commercial property as a dependent variable examined how the real estate values changed based on changes in the surrounding environment. Additionally, Chang and Chou (2010) examined the effect of building's environmental characteristics on the economic benefits of urban real estate market. They concluded that although factors specifically associated with the project's greenness such as benefits, implementation and promotion method, and the building space design including position and area, planting allocation, and maintenance and management of buildings negatively impact the building construction cost, the building's environmental characteristics had provided a positive impact on the urban real estate markets. Table 2.2 summarizes the findings of these studies including the external influence factors and their conclusions.

Table 2.2. Effect of Environmental Determinants on Real Estate Values

	Dependent variable	Independent variable	Conclusion
Hough and Kratz (1983)	Commercial property value	Exterior design	New buildings with excellent aesthetic values have a positive impact, but not old aesthetic buildings.
Weinberger (2001)	Commercial property value	Light rail	The proximity of light rail is related to property value and a rent benefit. It affects both residential and commercial property values positively.
Hui et al. (2007)	Residential property value	Sea view, Green belt area, Air quality, Noise level, Accessibility	Householders are willing to pay for better environmental qualities.
Chun et al. (2011)	Commercial property value	Visibility	Better visibility raises the real estate value.
Chang and Chou (2010)	Neighborhood property value	Building's environmental characteristics	Green building design has a positive impact on urban real estate value.

The Real Estate Value of a Commercial Building Obtained via the Hedonic Pricing Model

The hedonic approach method utilizes measures of the social capital or the value of the environment based on cross sectional data for real estate values such as residential real estate prices or land prices. Note that when measuring the value of an environment using cross section data such as land price, it is important to separate the non-environmental and environmental elements (Lee 2006; Zhang 2010). As Can (1992) pointed out, the "hedonic price regression model is a common approach to measure the neighborhood effect which includes a set of characteristics of the socio-economic and physical make-up". Kim and Son (2011) agreed, commenting that the "hedonic price model has useful functions when the research analyzes a heterogeneous market such as a real estate market, a labor market, an automobile market and so on." Baum and Mackim (1989) and Dunse and Jones (1998) noted that the hedonic approach method was generally utilized to measure the value of houses in the United Kingdom, which tend to be affected by the surrounding environment.

Researchers interested in real estate values in the United States have applied the hedonic price method in studies of commercial properties, reporting that the hedonic price method offers a useful way to appraise the real estate value of commercial buildings (Hough and Kratz 1984; Weinberger 2001; Chun et al. 2011; Fisher et al. 1994). Chun et al. (2011) applied the hedonic price model to derive movements in commercial real estate values based on the change of visibility by utilizing the appraisal total real estate tax, which directly represents the commercial property value. Interestingly, Weinberger (2001) chose to look at the rental rates and rental transaction data, arguing that the rental rates are much more elastic than the sales price and is also more sensitive to changes in market conditions. As rental transactions are performed more frequently than sales transactions, more data becomes available resulting in greater accuracy. Accordingly, in the hedonic price model, the measure of the price was assigned as a dependent variable and other characteristics such as the space and lease terms, location, and transaction year were assigned as independent variables. These assignments made it possible to analyze the relationship of the shadow price and the market value with other characteristics. Moreover, assumptions such as the market status, number of markets, and researcher's background, among others, were established based on the justification inherent in hedonic price modeling for this research (Fisher et al. 1994).

Research Question and Objectives

The purpose of this research is to examine the impact of LEED certified buildings on real estate values in the surrounding neighborhood. The research question guiding the research was whether LEED certified buildings have an impact on the real estate values of conventional buildings in the neighborhood. One hypothesis and three objectives were established as follows:

Hypothesis

The average market value of conventional commercial buildings in the neighborhood is changed when a LEED certified building is developed next to conventional commercial buildings.

Objectives

- Define what is meant by "neighborhood".
- Identify the market value of buildings in NYC to measure their real estate value.
- Identify the relationship between the real estate values of the LEED certified buildings and those of conventional buildings under similar conditions in a neighborhood.

Methodology

Definition of key terminologies

- Market value

Boyce (1984) and Epley et al. (2002) conclude that market value is the most probable price that establishes a competitive and open market under all conditions requisite to rational, well-informed, and fair buyers and sellers, where neither is under undue stimulus. This research focuses specifically on New York City (NYC), and the Department of Finance in the city defines the market value for the annual taxable value of buildings located in the five boroughs. It is the first step to estimate the property's market value for an annual property tax (www.nyc.gov).

- Commercial building

The definition of commercial building has several different meanings depending on the research field. Here we are looking at a wide range of real estate so various types of building are included in the definition of commercial building. Hence, the definition of commercial real estate provided by The Wall Street Journal (2010) was adopted, namely any property owned to produce income such as multi-family commercial real estate, retail space real properties, and office buildings and complexes.

Data Collection

For this project, the list of LEED certified buildings from the LEED certified Project Directory on the USGBC website[4] was used, which includes all the LEED certified and registered projects worldwide that have been enrolled by the project owners. According to the USGBC website, as of April 2, 2012, there were 46,706 LEED certified projects, located all over the world. Of these, the top 10 Gross Domestic Product (GDP) cities in the United States accounted for 7.4%, 3,472 LEED certified projects, and as the city with the highest GDP in the US, NYC has 491 LEED certified projects. The Public LEED Project Directory operated by USGBC, released on June 14, 2012, indicated that as of that date 208 LEED certified buildings were located in NYC. The relevant data sets could be downloaded through the USGBC website with a solid format. However, the specific information contained in the data sets from the Public LEED Project Directory lacked coherence and provided limited details for each LEED certified building because the information on each LEED certified building was provided by building stakeholders and thus the information depth lacked consistency. USGBC did not make a sufficient effort to manage and control the information depth when maintaining the consistency of the data sets and the quality of the data provided was therefore insufficient for the purposes of this study in many cases. NYC's Department of Finance estimates and provides annual

[4] http://www.usgbc.org/LEED/Project/CertifiedProjectList.aspx

market values for each unit in particular types of building, such as multi-family residential or condominiums, rather than the annual market value for the whole building. According to the conditions of the available data sets, 76 LEED certified buildings were selected randomly as the sample group based on their geographical constraints and fidelity in the LEED certification data provided by USGBC (U.S. Department of Commerce 2011). 128 conventional commercial neighboring buildings were identified for comparison. Geographic information on the LEED certified buildings and conventional buildings was obtained through the 'OASISNYC' system operated by the Center for Urban Research at the City University of New York Graduate Center, which links the GIS data to the New York City government's information system. The market value data for the selected buildings was collected through the website 'NYC Finance[5], which is an official website operated by the city government. This market value data is updated annually and cover the period 2006 to 2013. Lastly, a range of GIS data related to NYC are produced and provided by various organizations, including NYC OpenData, the Department of City Planning of NYC, and NYC Information Technology and Telecommunications. The physical addresses of all the selected buildings were converted to geographic information, namely longitude and latitude, using 3 geocoding online services: Google map, Yahoo map, and the GIS Research Laboratory at the University of Southern California. Additionally, the Consumer Price Index (1982-1984=100) for the NY-NJ-CT-PA region was applied to the market value data to adjust for inflation and deflation for the years 2006 to 2013.

Variables

Three sets of variables were used in this research: dependent variables, independent variables, and control variables. Table 2.3 presents the data included in each variable.

[5] http://webapps.nyc.gov:8084/CICS/fin1/find001i

Table 2.3. Research Variables

Dependent variable	Average unit market value ($/sq-ft) of each conventional commercial building in the neighborhood (2006-2013)
Independent variable	Average unit market value ($/sq-ft) of each LEED certified building (2006-2013)
Control variables	Number of adjacent streets for each conventional commercial building
	Time since LEED certification (in years)
	LEED certified points
	Distance from the nearest subway entrance to a conventional building
	Conventional commercial building floors
	Conventional commercial building area
	Conventional commercial building age (based on a built year/excluding a renovated year)

Hedonic Price Model

Four assumptions have been established for the hedonic price model used in this research as it is not generally easy to determine how all the variables relevant to the real estate values of buildings relate to the hedonic price model.

- All third party-provided data have been measured and recorded accurately.
- The market is in equilibrium and a single market
- CPI index is used to adjust the inflation or the deflation.
- The independent variables have no correlation between each other.

There are four different hedonic price functions, shown below, but the linear function was utilized in this research because it was deemed appropriate for determining the presence or absence of correlations between LEED certified buildings and surrounding conventional commercial buildings in a specific neighborhood. SPSS was used to analyze the correlations between the average market values of the LEED certified buildings and their adjacent commercial counterparts.

Linear function	$P = a_0 + a_1Z_1 + \cdots\cdots + a_nZ_n$
Log-linear function	$P = a_0 + a_1\log Z_1 + \cdots\cdots + a_n\log Z_n$
Semi-log function	$\log P = a_0 + a_1Z_1 + a_2Z_2 + \cdots\cdots + a_nZ_n$
Log-log function	$\log P = a_0 + a_1\log Z_1 + \cdots\cdots + a_n\log Z_n$

Note: $a_{n:}$ a coefficient, $Z_{n:}$ variables

Geographic Information System

A spatial analysis of the distribution of LEED certified buildings in the NYC region and the domains of the neighborhoods containing LEED certified buildings involved GIS mapping to identify the spatial characteristics using GIS data taken from several open databases linked to the NYC government. The GIS map of the distribution of LEED certified buildings in NYC shown in Figure 3 was developed with ArcGIS10 serviced by ESRI based on information on the longitude and latitude for each LEED certified building derived using physical addresses and zip codes provided by USGBC. In addition, GIS was used to identify adjacent building for this research.

Analysis

Spatial Analysis

As of April 2012, 97.1% of all the LEED certified projects in NYC were located in Manhattan, but to maintain diversity and ensure a good mix of neighborhoods; as many as possible LEED certified buildings from other parts of the city were included in this study. Hence, 62 of the LEED certified buildings in the study were in Manhattan and 14 were in other parts of the city (5 each from the Bronx and Brooklyn, 3 from Queens, and 1 from Staten Island). Figure 2.4 illustrates the distribution of the LEED certified building samples based on their NYC GIS data.

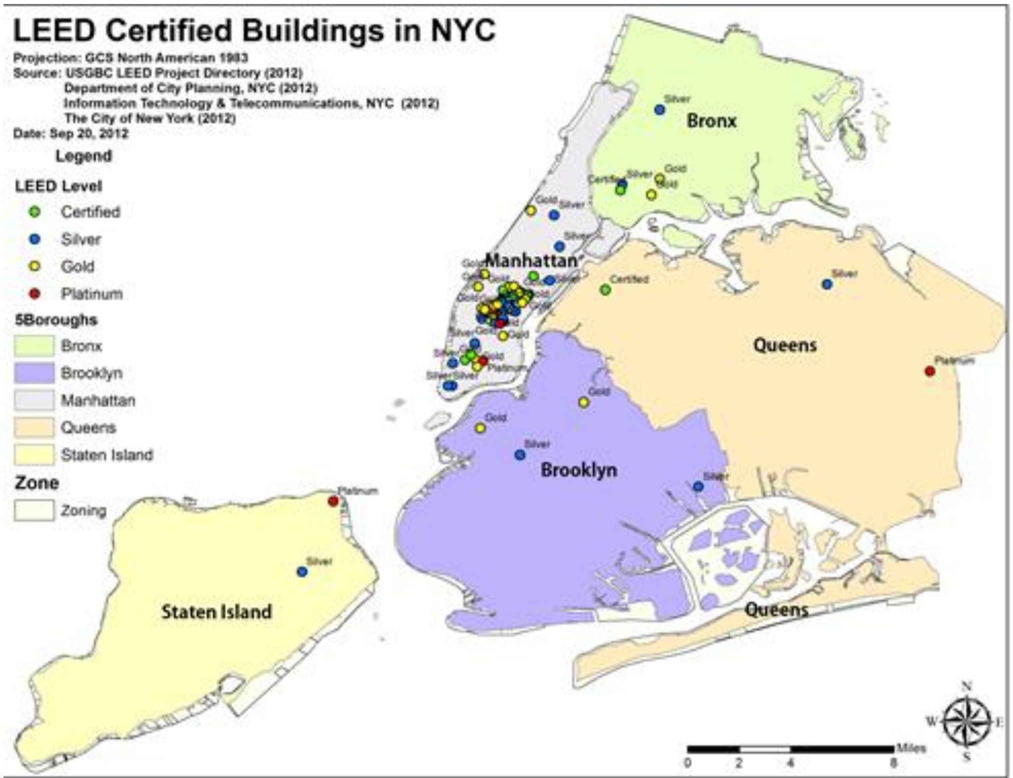

Figure 2.3. Distribution of LEED certified building sample

Descriptive Analysis

The LEED certified buildings in the study sample had earned scores over a relatively wide range from 36.84 percent to 77.27 percent of full marks. Their mean and standard deviation of LEED certified period were 1.77 years and 1.232 years which mean that most of the LEED certified building samples were actually finished and occupied between 2009 and 2011. The market value of the LEED certified buildings for the period from 2006 to 2013 presents a similar standard deviation, which indicates that all the market value/sq-ft information for the LEED certified buildings represents a normal distribution in Table 2.4. However, the data on the market value/sq-ft of the adjacent buildings exhibits a wider distribution, especially for the periods 2007-2008 and 2012-2013. The age of the adjacent buildings selected for the comparison ranged from 2 to 113 years based on their built year. “Adjacent street” indicates that a street bordered a LEED certified building, thus increasing the exposure of building to pedestrians or drivers and the accessibility of building users. The mean of the number of adjacent streets for the buildings was 1.57, which indicates that a LEED certified building usually adjoined more than 1 street, and the maximum number of adjacent streets was 3. No LEED certified building in the sample group occupied an entire city block. The mean of the distance from the nearest subway station to a conventional commercial building in NYC was found to be 0.216 miles, and the maximum distance 2.92 miles, in the borough of Staten Island. Especially, the variation of the mean unit market value of LEED certified building was smaller than that of adjacent conventional commercial buildings, as shown in Figure 2.5, which suggests that LEED certified buildings had a limited impact on their unit market values over time. The overall descriptive results are shown in Table 2.4 below.

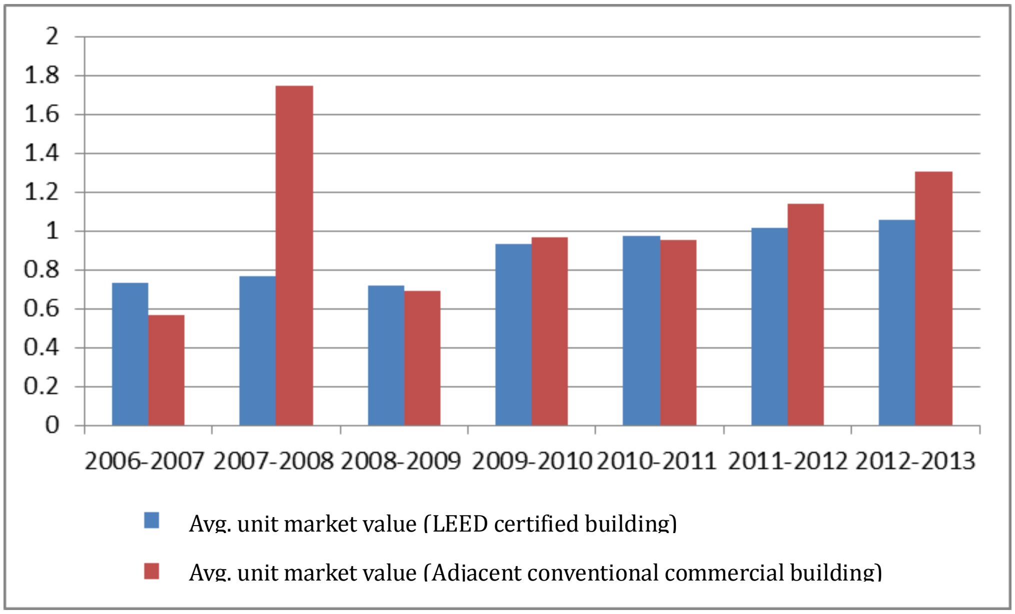

Figure 2.4. Variation in the unit market values of LEED certified buildings and adjacent conventional commercial buildings

Table 2.4. Descriptive Analysis Results

		N	MIN	MAX	MEAN	STDEV
LEED certified building (dollar/sq-ft)	2006-2007 average unit market value	3	0.33	1.03	0.73	0.361
	2007-2008 average unit market value	3	0.33	1.10	0.767	0.395
	2008-2009 average unit market value	8	0.44	1.27	0.716	0.307
	2009-2010 average unit market value	22	0.39	2.08	0.934	0.474
	2010-2011 average unit market value	38	0.08	2.07	0.97	0.484
	2011-2012 average unit market value	62	0.11	2.53	1.015	0.55
	2012-2013 average unit market value	75	0.08	3.67	1.055	0.613
Distance from the nearest subway entrance to a conventional commercial building (mile)		128	0.01	2.92	0.216	0.421
No. of adjacent streets		128	1	3	1.57	0.66
Adjacent building area (sq-ft)		128	2	113	77.15	31.73
Adjacent building floor		128	1	58	12.61	12.873
Adjacent conventional commercial building (dollar/sq-ft)	2006-2007 average unit market value	5	0.144	0.845	0.563	0.257
	2007-2008 average unit market value	5	0.159	6.456	1.745	2.646
	2008-2009 average unit market value	12	0.012	2.735	0.693	0.736
	2009-2010 average unit market value	37	0.022	3.254	0.966	0.728
	2010-2011 average unit market value	65	0.077	3.125	0.953	0.652
	2011-2012 average unit market value	104	0.082	7.353	1.139	0.991
	2012-2013 average unit market value	124	0.047	17.53	1.302	1.883

Note: ※ Data that were not available have been excluded from the analysis because the NYC government dataset did not include the market values of several buildings for certain years.

Regression Analysis

The data were analyzed using SPSS Statics version 19. The partial correlation function was applied because of the control variables and the linear regression function was also utilized to determine the impact of each variable on the dependent variable. The result of partial correlation is presented as P-value to indicate that the research model is satisfied, with significance, 0.041, represented by value lower than 0.05. As at least one coefficient for an independent variable is not 0, the alternative hypothesis is accepted and the null hypothesis, where all coefficients of independent variable are 0, rejected. The results are shown in Table 2.5.

Table 2.5. Correlation Results

<table>
<tr><th colspan="3">Control variables</th><th>Avg. unit market value of LEED certified building</th><th>Avg. unit market value of adjacent building</th></tr>
<tr><td rowspan="6">LEED certification score & LEED certification period & Adjacent bldg. built year & Distance from adjacent bldg. to the nearest subway station & No. of streets for an adjacent bldg. & No. of floor of adjacent bldg. & Area of adjacent bldg.</td><td rowspan="3">Avg. unit market value of LEED certified building</td><td>Correlation</td><td>1.000</td><td>.186</td></tr>
<tr><td>Significance (2-tailed)</td><td></td><td>.041</td></tr>
<tr><td>Degree of freedom</td><td></td><td>119</td></tr>
<tr><td rowspan="3">Avg. unit market value of adjacent building</td><td>Correlation</td><td>.186</td><td>1.000</td></tr>
<tr><td>Significance (2-tailed)</td><td>.041</td><td></td></tr>
<tr><td>Degree of freedom</td><td>119</td><td>0</td></tr>
</table>

This research model resulted in a relatively low R^2 value, 0.229, which implies that the variation in market value is only partially explained by the variables and the functions examined. The results suggest that the variables include the average market values of LEED certified building and adjacent building of LEED certified building, the LEED certification score, the number of streets for the comparable conventional building, the distance from a commercial conventional building to the nearest subway entrance, a conventional commercial building area, and the number of floors of the conventional commercial building. Particularly, the average market value of the LEED certified building, the number of adjacent streets to the adjacent commercial conventional building, and the LEED certification score have a positive impact on the dependent variable, with t-values of 2.069, 1.874, and 3.648, respectively. On the other hand, the distance from the nearest subway entrance to the adjacent commercial building and the adjacent commercial conventional building's floor and area exert a negative impact on the dependent variable, with t-values of -2.314 and -2.832, respectively. Tables 2.6 and 2.7 present the results of the linear regression.

Table 2.6. Results of the Linear Regression (ANOVA[b])

Model		Sum of Squares	Degree of freedom	Mean Square	F	Sig.
1	Regression	71.160	8	8.895	4.413	.000[a]
	Residual	239.841	119	2.015		
	Total	311.001	127			

a. Predictors: (Constant), Adjacent bldg. built year, LEED certification period, Avg. market value of LEED certified bldg., No. of street of adjacent bldg. Distance to the nearest subway station, LEED certification score, No. of floor of adjacent bldg., Area of adjacent bldg.

b. Dependent variable: Avg. market value of adjacent bldg.

Table 2.7. Results of the Linear Regression (Coefficients)

Model	Unstandardized Coefficients		Standardized Coefficients	T	Sig.
	B	Std. Error	Beta		
(Constant)	-.113	.822		-.138	.890
Avg. unit market value of LEED certified bldg.	.595	.287	.174	2.069	.041
LEED certification score	.019	.010	.175	1.874	.063
LEED certification period	-.066	.098	-.060	-.680	4.98
No. of street of adjacent bldg.	.868	.238	.366	3.648	.000
Distance to the nearest subway station from adjacent bldg.	-.791	.342	-.213	-2.314	.022
No. of floor of adjacent bldg.	-.045	.016	-.372	-2.832	.005
Area of adjacent bldg.	$-2.880E^{-7}$	.000	-.060	-.443	.658
Built year of adjacent bldg.	-.007	.005	-.146	-1.596	.113

a. Dependent variable: Avg. unit market value of adjacent conventional commercial bldg.

Findings and Discussion

This research examined the correlations between the real estate values of LEED certified buildings and their commercial conventional counterparts in the same neighborhood by looking at their average unit market values. The hypothesis guiding the research was that the average unit market value of conventional commercial buildings in the neighborhood is changed when a LEED certified building is developed next to conventional commercial buildings, and this research accepts this hypothesis. As described in Figure 2.5, although the descriptive analysis results notes that the average unit market values of LEED certified buildings over the research period were not always higher than those of adjacent conventional commercial buildings, the LEED certified buildings tended to have more stable average unit market values than the adjacent conventional commercial buildings over the research period. In addition, the pattern of changes in the average unit market values of adjacent conventional commercial buildings tended to indicate a similar pattern to those of the LEED certified buildings except for the years 2010 and 2011. In these two years, the average unit market values of LEED certified buildings increased compared to LEED certified buildings in earlier years, but those of adjacent conventional commercial buildings for the years 2010 and 2011 decreased compared to adjacent conventional commercial buildings in previous years. Moreover, most of the buildings adjacent to the buildings chosen for this research were located near a subway entrance, at an average distance of around 0.216 miles. The Metropolitan Transportation Authority (MTA) of NYC states that the annual subway ridership is 2.5 times higher than the annual bus ridership in NYC and the city has a high commuter population; thus, in this study, only subway entrances were considered as a major environmental factor, not bus stops. Interestingly, according to the analysis, the distance from an adjacent conventional commercial building to the nearest subway entrance has a negative coefficient value for the linear function. Above all, although the R^2 value is relatively lower than other R^2 values from other studies (Bloom et al. 1984; Hough and Kratz 1984; Weinberger 2001; Hui et al. 2007), this research demonstrates that the positive impact variables (average market value of LEED certified building and the number of adjacent streets of conventional commercial buildings) and the negative variables (the distance from the nearest subway entrance to a conventional commercial building and conventional commercial building's floor) have a relationship, albeit a weak one, to the market value of commercial conventional buildings in the same neighborhood in the NYC region. In addition, the rest of the variables (LEED certification score and the area and the built year of adjacent conventional commercial building) are not significant as the p-value is greater than the significance level of 0.05. Although LEED certification increases a building's own property value, as shown in previous studies (McGraw-Hill Construction 2008; Miller et al. 2008; Eichholtz et al. 2010; Fuerst and McAllister 2011), the statistical results of this research shown in Table 2.7 reveal that only the average unit market value of a LEED certified building has a positive effect on the average unit market value of adjacent conventional commercial buildings. Moreover, the characteristics of LEED certification such as the certification score and certification period are not statistically significant for the correlation between the independent and dependent variables. Therefore, these findings indicate that although LEED certification has a positive economic impact on adjacent conventional commercial buildings indirectly through changing the average unit market values, which are caused by achieving LEED certification, these two specific characteristics of LEED certification have little impact on the property values of adjacent conventional commercial buildings. Consequently, in addition to the potential environmental benefits gained by LEED certification, neighboring building stakeholders may also receive economic benefits from LEED certification undertaken by their neighbors. These findings may provide a starting point for a deeper examination of how LEED certified buildings support efforts to achieve the '3Ps' of sustainability from a socio-economic standpoint and suggest a new approach that might usefully be applied to convince skeptics of the economic benefits of constructing LEED certified buildings.

Limitations and Future Research

This research focused on the impact of LEED certified buildings on the market value of adjacent conventional commercial buildings as an environmental factor. The actual market value of all types of buildings was determined by numerous environmental factors, as mentioned earlier. Besides the numerous environmental factors, several other limitations existed for this research. First, a limited number of samples were selected in a specific geographical area, in this case a single unique urban environment (NYC), with most of the sample being located in Manhattan. Second, only the linear function for the hedonic price method was utilized. Third, other variables that measure the economic value of buildings could be applied in addition to the variable used here, market value, and it would also be possible to collect economic value data from the private sector as well as the public sector. Fourth, only a limited number of independent variables not related to each other were utilized; other variables such as policy changes, economic conditions, and several other features of the existing environment could be considered and the relationship between independent variables could be identified as well. Fifth, this research redefined a limited area and a limited number of buildings as the surrounding neighborhood in order to isolate the effects of multiple LEED certified buildings on conventional buildings in the surrounding area. Future studies would further explore these density effects. Lastly, this research assumed that the real estate market is in equilibrium and acts as a single market to gauge the impact of the LEED certified buildings. Given these limitations, it was difficult to determine the true magnitude of the impact of each independent variable on the dependent variable. Consequently, the findings pertained only to this specific case, and it was difficult to generalize our findings to a wider population without further study. It would also be interesting to investigate the optimum number of LEED certified buildings or the optimum density of LEED certified buildings in a specific region to maximize profit and to consider various economic concepts that might affect the sustainability of LEED certified buildings and the LEED certification. It seemed highly probable that future research would continue to integrate economic concepts into the economic valuation of green building certifications.

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References

Barbiroli, G. (2006). Eco-efficiency or/and eco-effectiveness? Shifting to innovative paradigms for resource productivity, *International Journal of Sustainable Development and World Ecology*, 13, pp. 391-395.

Baum, A. and Mackim, D. (1989). *The Income Approach to Property Valuation*, Routledge, London.

Bloom, G. F., Weimer, A. M., and Fisher, J. D. (1984). *Real Estate, 8th Ed.*, John Wiley & Sons, New York.

Booz Allen Hamilton (2009). *Green Jobs Study*, Booz Allen Hamilton Inc., Greensboro, North Carolina.

Boyce, B. N. (1984). *Real estate appraisal terminology revised Ed.*, Ballinger Publishing Company, Cambridge, Massachusetts.

Can, A. (1992). Specification and estimation of hedonic housing price models, *Regional Science and Urban Economics* 22 (1992) pp. 453-474.

Chang, K. and Chou, P. (2010). Measuring the influence of the greening design of the building environment on the urban real estate market in Taiwan, *Journal of Building and Environment*, 4S, pp. 2057-2067.

Chun, B., Guldmann, J. M., and Seo, W. (2010). Impact of Multi-dimensional Isovist on Commercial Real Estate Values in CBD Area Using GIS, *Journal of Seoul Studies*, 12(3), pp. 17-32.

Clapp, J. M. and Wang, Y. (2006). Defining neighborhood boundaries: Are census tracts obsolete?, *Journal of Urban Economics*, 59(2), pp. 259-284.

Dunse, N., and Jones, C. (1998). A hedonic price model of office rents, *Journal of Property Valuation and Investment*, 16(3), pp. 297-312.

Eichholtz, P., Kok, N., and Quigley, J. (2010). *The Economics of Green Building, Berkeley Program on Housing and Urban Policy*, Institute of Business and Economic Research.

Epley, D. R. and Rabianski, J. (1981). *Principles of real estate decisions*, Addison-Wesley Publishing Co. Inc., Philippines.

Epley, D. R., Rabianski, J. S., and Haney, R. L. JR. (2002). *Real Estate Decisions*, Thomson Learning, Ohio.

Fisher, J. D., Geltner, D. M., and Webb, B. R. (1994). Value Indices of Commercial Real

Estate: A Comparison of Index Construction Methods, *Journal of Real Estate Finance and Economics*, 9, pp. 137-164.

Fowler, K. M. and Rauch, E. M. (2006). *Sustainable Building Rating Systems Summary*, The Pacific Northwest National Laboratory.

Fuerst, F. and McAllister, P. (2011). Green Noise or Green Value? Measuring the Effects of Environmental Certification on Office Values, *Journal of Real Estate Economics*, 39(1), pp. 45-69.

Goodman, A. C. (1981). Housing Submarkets Within Urban Areas: Definitions and Evidence, *Journal of Regional Science*, 21(1981), pp. 175-185.

Hough, D. E. and Kratz, C. G. (1984). Can Good Architecture Meet the Market Test?, *Journal of Urban Economics*, 14, pp. 40-54.

Hui, E. C. M., Chau, C. K., and Law, M. Y. (2007). Measuring the neighboring and environmental effects on residential property value: Using spatial weighting matrix, *Journal of Building and Environment*, 42, pp. 2333-2343.

Kerstens, S. M., De Ridder, R., Hof, A., Alberts, J., Mulhall, D., and Dale, D. (2001). Towards eco effective sustainable sanitation for the city of Almere, *Journal of Water Practice and Technology*, 6(2).

Kim, K. and Son, J. (2011). *Real Estate Economics*, KU Smart Press, Seoul, South Korea.

Lee, D. (2004). *Ecological Implications of Landscape Elements in Traditional Korean Villages*, Seoul National University Press, Seoul, South Korea.

Lee, J. (2006). *Environmental economics*, Pakyoungsa Publishing, Seoul, South Korea.

Lee, Y. (2008). A review of the hedonic price model, *Journal of the Korea Real Estate Analysis Association*, 14(1), pp. 81-87.

McAllister, C. (2011). Global Strides: LEED International Program Advances Green Building and Green Building Knowledge on a Global Scale, *Environmental Design and Construction*, Vol. 32(5), 27.

McDonough, W. and Braungart, M. (2002). *Cradle to Cradle.*, North Point Press, New York, pp. 53-54.

McGraw-Hill Construction (2008). *Global Green Building Trends–Market Growth and Perspectives from Around the World*, Smart Market Report: Design and construction intelligence, McGraw-Hill, New York.

Miller, N., Spivey, J., and Florance, A. (2008). Does Green Pay Off?, *Journal of Real Estate Portfolio Management*, 14(4), pp. 385-398.

O'Sullivan, A., *Urban economics 7th Ed.*, McGraw-Hill Co. Inc., New York, 2009.

Pearce, A. R., Ahn, Y. H., and HanmiGlobal (2012). *Sustainable buildings and infrastructure paths to the future*, Routledge, New York.

Pearce, A. R. and Fischer, C. L. J. (2001). *Systems-Based Sustainability Analysis of Building 170, Ft. McPherson, Atlanta, GA*, Army Environmental Policy Institute.

Troianovski, A. (2010). Signs of recovery for office market, *The Wall Street Journal*, October 5, 2010.

U.S. Department of Commerce (2011). *New Release: GDP by Metropolitan Area, Advance 2010, and Revised 2007–2009.*

Weinberger, R. R. (2010). *Commercial property value and proximity to light rail: A Hedonic Price Application,* University of California, Berkeley, CA.

Zhang, Y. (2010). Residential Housing Choice in a Multihazard Environment: Implications for Natural Hazards Mitigation and Community Environmental Justice, *Journal of Planning Education and Research,* 30(2), pp. 117-131.

Chapter 3

The Impact of LEED-Energy Star Certified Office Building on the Market Value of Adjoining Buildings in New York City

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Abstract: Green building certifications offer a useful way to advance objective evaluations of the sustainability of building, and both the Leadership in Energy and Environmental Design (LEED) and Energy Star certifications have been designed to improve the negative environmental impacts of buildings on society and provide positive economic benefits to certified building stakeholders. A positive economic impact is also required to satisfy a part of the triple bottom line of sustainability for these certifications, so this study examined the economic impact of LEED and/or Energy Star certified office buildings on the market values of adjoining buildings in Manhattan, New York City using spatial and statistical analysis approaches. Our findings revealed a positive impact of LEED and/or Energy Star certified office buildings on the unit market values of their adjoining buildings from an economic standpoint when considering the major features of LEED certification, LEED certification level and LEED certification coverage.

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Introduction

The importance of sustainability is widely recognized and is now a priority in several aspects of our daily lives. As a result, research in sustainability is no longer limited to economics, humanities, and the social sciences but has become a subject of interest to those working in fields such as environmental science and engineering. According to those seeking to diffuse a greater awareness of the importance of sustainability to the general public (Kerstens et al. 2011; Suh et al. 2013), a useful way to achieve this was to apply the principle of the '3Ps', namely *People, Planet, and Profit*, which was simply another way of presenting the triple bottom line of sustainability propounded by Freer Spreckley (1981).

In tune with present day needs, the construction industry is also transforming itself to improve performance at every stage of the building life cycle in support of a more sustainable construction industry. As part of this effort, several developed countries have established green building certification programs to evaluate the sustainability of green building as an important part of capital project sustainability initiatives and diffuse the certifications to their own construction industries and those in developing countries (Fowler and Rauch 2006; Eichholtz et al. 2010a; Eichholtz et al. 2010b; Pearce et al. 2012; Pearce and Kleiner 2013). In particular, two leading green building certifications have been developed in the United States, namely Leadership in Energy and Environmental Design (LEED) proposed by the United States Green Building Council (USGBC) in 1995 and launched officially in 2000, and Energy Star, developed by a joint program of the United States Environmental Protection Agency (USEPA) and the United States Department of Energy (USDOE) in 1992. These two certifications were designed to demonstrate superior energy performance through reduced energy consumption (Fuerst and McAllister 2010; McGraw-Hill Construction 2010). Simultaneously, research into the impact of LEED and/or Energy Star certification on the property values of certified buildings has shown that their property values tended to increase after achieving certifications and were generally higher than the property values of other comparable buildings in similar condition (McGraw-Hill Construction 2008; Miller et al. 2008; Eichholtz et al. 2010a; Eichholtz et al. 2010b; Fuerst and McAllister 2011).

Although the principle of supply and demand fundamentally applied to the appraisal of property values, the property values were also affected by numerous features such as the characteristics of the building and its surrounding environment (Epley and Rabianski 1981; Epley et al. 2002). Therefore, from an economic standpoint, the impact of LEED and/or Energy Star certification might not only be a feature of the property commodity itself but could also play a role in establishing the external features in the existing environment for surrounding buildings because the property value of a building was often appraised using a sales comparison approach, which was a common way to estimate property values (Almanzar 2012).

By identifying the impact of LEED and/or Energy Star certification on the property value of adjoining buildings of LEED and/or Energy Star certified building, this research investigated whether LEED and/or Energy Star certification of a building was indeed one of the economic factors that affected the property value of adjoining buildings. Furthermore, our conclusions are expected to expand the concept of "green" beyond simple environmental performance to include critical economic factors related to green building certification that take into account not only the notions of energy efficiency and environmentalism, but also the economic performance of both the certified buildings themselves and those in their surrounding neighborhood.

Background

Property values of LEED or Energy Star certified buildings

The first LEED and Energy Star certifications were awarded more than ten years ago, and several researchers have since studied the impacts of both certifications in terms of the effect on the property value of a certified building based on the accumulating data. Most studies (Ries et al 2006; Kok et al. 2011; Yu et al. 2011) have found that both LEED certification and Energy Star certification have a positive impact on the property value of buildings that achieve either one or both of the two certifications. Ries et al. (2006), Kok et al. (2011), and Yu et al. (2011) reported that the economic values of certified buildings increased after achieving LEED or Energy Star certification, which were designed to accomplish specific building performance objectives. These researchers evaluated the building performance and assessed the various direct or indirect economic benefits, such as the reduction in the consumption of water and energy, the improvement of health problems, the enhanced productivity of employees, and the increased property value of a certified building. The findings so far reported in the literature are as follows:

- Estimated savings of $281 million from 2000 to 2008 and potential savings of a further $4.8 billion predicted from 2009 to 2013 through the reduced energy consumption by LEED certified buildings in the US alone. A reduction in CO_2 emissions of around 2 million metric tons from 2000 to 2008 and a dramatic decrease in CO_2 emissions of about 34 million metric tons were predicted from 2009 to 2013 (Booz Allen Hamilton 2008).

- Reductions in energy use of 30 percent, carbon emissions of 35 percent, and water consumption of 30 to 50 percent, along with generating waste cost savings of 50 to 90 percent obtained from LEED certified buildings (Communication Department of the CEC Secretariat 2008).

- A positive correlation between a building's energy efficiency performance and sustainability performance in five key areas: human and environmental health, real estate market values, building owners' income and tenants' willingness to pay due to either LEED or Energy Star certification (Untied State Department of Energy 2008; United States Environmental Protection Agency 2006; 2013).

- Reductions in energy consumption after achieving LEED certification for a small sized office building, but the opposite result for a large sized office building (Scofield 2009).

- Conflicting conclusions regarding the construction costs for a green building due to the green features or technologies required by LEED or Energy Star certification (Herkel 2006; Muldavin 2010)

- An insignificant effect on the property cash flow (Muldavin 2010).

In addition, researchers have measured the impact of the certifications in terms of added property value as represented by the certified building's rental rates, unit sales price, vacancy or occupancy rate, and resale value rate (Miller et al. 2008; McGraw-Hill Construction 2010; Eichholtz et al. 2010a; Wiley et al. 2010; Fuerst and McAllister 2011). The results of previous studies comparing LEED or Energy Star certified buildings to comparable non-certified buildings under similar environmental conditions were summarized in Table 3.1.

Table 3.1. Comparison of property value benefits between LEED or Energy Star certified buildings and comparable non-certified buildings

Literature	Certification	Rental rates		Unit sales price		Occupancy rate		Resale value rate	
		C	N-C	C	N-C	C	N-C	C	N-C
Miller et al. (2008)	LEED	1.2-1.5	1			0.993-1.047	1	0.901	1
	Energy Star	1.05-1.09	1			1.01-1.035	1	1.053	1
McGraw-Hill Construction (2010)	LEED	1.01-1.06	1			1.025-1.064	1	1.068-1.109	1
	Energy Star	1.01-1.06	1			1.025-1.064	1	1.068-1.109	1
Eichholtz et al. (2010a)	LEED	1.06	1			1.023	1	0.89	1
	Energy Star	1.065	1			1.023	1	1.129	1
Wiley et al. (2010)	LEED	1.152-1.173	1			1.162-1.179	1		
	Energy Star	1.073-1.089	1			1.1-1.11	1		
Fuerst & McAllister (2011)	LEED	1.05	1	1.25	1				
	Energy Star	1.04	1	1.26	1				

Note. C: Certified building, N-C: Non-certified building

The data shown in Table 3.1 provided some interesting results as follows:

- Buildings with Energy Star certification commanded a resale value rate of about five to twelve percent, but the resale value rate of LEED certified buildings was lower than that of the resale value rate of comparable non-certified buildings at the time of the study (Miller et al. 2008; Eichholtz et al. 2010a).

- The unit sale prices of both LEED and Energy Star certified buildings were higher than those of comparable non-certified building by about 25 percent (Fuerst and

McAllister 2011).

- There was a difference in opinions regarding whether or not the rental rates premium depended on the certification, either LEED or Energy Star: Miller et al. (2008) and Wiley et al. (2010) concluded that the rental rates of LEED certified buildings was about five percent higher than that of Energy Star certified buildings, but the remaining three studies reported little difference between the two certification types for building rental rates (McGraw-Hill Construction 2010; Eichholtz et al. 2010a; Fuerst and McAllister 2011).
- Miller et al. (2008) indicated that the occupancy rate of LEED certified buildings was not always higher than that of comparable non-certified buildings; in some cases the occupancy rate of LEED certified buildings was lower than that of comparable non-certified buildings by 0.7 percent.

Overall, the researchers agreed that most buildings that achieved LEED or Energy Star certification benefit from a positive impact due to an increase in the buildings' property values.

However, Dermisi (2009) argued that not all levels of LEED certification had a positive influence on a building's economic property value and a particular level or type of LEED certification had little or no positive impact on the economic value of a certified building. In particular, the p-value of LEED-New Construction (LEED-NC) at the Silver level was significant, and this study suggested that it was necessary to determine the reason for this negative effect. Moreover, although the negative effect of LEED-Core and Shell (LEED-CS) at the Certified level was statistically significant, the result was biased due to the small number of observations. Several of the previous studies shown in Table 3.2 have suggested that various general physical features that were not related to the LEED or Energy Star certification of the certified building, such as building class, rentable building area, building age, and so on, could also have an impact on the economic values of certified buildings either positively or negatively. Table 3.2 presents the different economic benefits of LEED or Energy Star certified buildings caused by various features of buildings, including specific characteristics of LEED certification and other building characteristics.

Table 3.2. The impact of internal characteristics of LEED or Energy Star certified buildings on their property economic values

	Certification	Positive impact	Negative impact
Dermisi & McDonald (2011)	LEED	Sales price ($/sq-ft): LEED	
	Energy Star	Sales price ($/sq-ft): Energy Star	
	Other	Sales price ($/sq-ft): Bldg. class; Occupancy rate; Renovation	Sales price ($/sq-ft): Built before 1970s -23.3%; Conference facility -9.4%
Fuerst & McAllister (2011)	LEED	Rental rates ($/sq-ft): LEED all levels	
	Energy Star	Rental rates & sales price ($/sq-ft): Energy Star	
	Other	Rental rates ($/sq-ft): Stories; Bldg. class A&B Sales price ($/sq-ft): Ages; Bldg. class A&B	Rental rates ($/sq-ft): Ages; Size Sales price ($/sq-ft): Size
Eichholtz et al. (2010a)	LEED	Occupancy rate by rent: LEED Registration (+7.9%); LEED Score 40 (+2.1%); LEED Score 60 (+20.1%)	
	Energy Star	Occupancy rate by rent: Energy Star certification (+4.9%) Capitalization rate of the rent increment (+8%)	
Willey et al. (2010)	LEED	Rental rates premium ($/sq-ft) +15.2-17.3%; Occupancy rate +16.2-17.9%; Sales price premium ($/sq-ft) +129.18	
	Energy Star	Rental rates premium ($/sq-ft) +7.3-8.9%; Occupancy rate +16.2-17.9%); Sales price premium ($/sq-ft) +29.71	
Dermisi (2009)	LEED	Assessed value: Certification of medium sized (approximately 220,000 sq-ft) buildings using LEED-CS at the Gold or Silver level; LEED-EB at the Gold level Market value: LEED-EB at the Silver or Gold level; LEED-NC at the Gold level	Assessed value: Certification of small sized (approximately 100,000 sq-ft) buildings using LEED-NC at the Silver level; LEED-CS at the Certified level Market value: Certification of small sized (approximately 100,000 sq-ft) buildings using LEED-NC at the Silver level
	Energy Star	Assessed value and Market value	
	Other	Assessed value: Rentable bldg. area; Year built Market value: Rentable bldg. area; Bldg. class; Year built	

The impact of changes in the external features of the existing environment on local property values

As mentioned earlier, property values were generally determined by the principle of supply and demand, and the property value of a specific building is affected by the actual property commodity itself and features of the external environment such as social factors, physical factors, economic factors, and government and political factors (Boyce 1984; Epley and Rabianski 1981; Bloom et al. 1982; Epley et al. 2002; Friedman et al. 2013). There were several reports in the literature of research into the effect of features of the external environment on property values, and researchers have concluded that economic changes occur in property values in areas that have undergone a significant change in their neighborhood environment (Weinberger 2001; Kim et al. 2003; Mansfield et al 2005; Hui et al. 2007; Lin et al. 2009; Chun et al. 2011; Saphores and Li 2012). These studies looked at changes in property values due to the addition of new large-scale infrastructure projects that included public green areas or involved changes in the surrounding environment that affected the quality of human life either directly or indirectly. These studies agreed that changing external environmental features had a significant impact on the property value of a specific area or a building, and identified the type of change that occurred. Table 3.3 summarized the findings of these studies.

Table 3.3. Effects of environmental determinants on property values

	Dependent variable	**Independent variable**	**Conclusions**
Weinberger (2001)	Commercial property values	Light rail	Public transportation was linked to improved property values and a rent benefit, Light rail transit affected both residential and commercial property values positively.
Kim et al. (2003)	Residential property values	Air quality improvement	Marginal willingness to pay by buyers was about 1.2%~1.4% for better air quality, which was included in the price of the property.
Mansfield et al. (2005)	Residential property values	Urban forests	Greenness and fore-entrance added value to parcels of land; however, private forests provided more important sources of value to houses in the area than institutional forests.

Table 3.3 (Continued). Effects of environmental determinants on property values

Hui et al. (2007)	Residential property values	Sea view Green belt area Air quality Noise level Accessibility	Householders were willing to pay for better environmental quality.
Lin et al. (2009)	Residential property values	Foreclosure	The impact of foreclosure decreased with distance, and the significant negative impact extended over a radius of 0.9 km or about 2,700 feet (roughly 10 blocks).
Chun et al. (2011)	Commercial property values	Visible space	A better view leaded to higher property values.
Saphores and Li (2012)	Residential property values	Urban green area	Trees and grassy areas in a neighborhood benefited most nearby properties.

In addition, Chang and Chou (2010) examined the effect of a building's green design, which they included in the physical classification category for their study of the economic benefits of green building design for urban real estate markets. They concluded that factors significantly associated with the project's greenness such as greening benefits (urban microclimate environment, urban disaster prevention and security, urban environment quality, economic benefits, and harmony with human health and wellness), implementation and promotion methods, and the building space design, including position and location, planting allocation, and the maintenance and management of the building, all had a negative impact on the building's construction costs, and that the building's green design had a positive impact on not only the building's reputation but also the local urban real estate market. Moreover, Suh et al. (2013) conducted a statistical analysis that demonstrated correlation between the market value of LEED certified buildings and the market values of adjoining buildings in New York City.

The meaning of market value for buildings in New York City.

Theoretically, the market value represented the most probable price of a property if determined in a competitive and open market under all conditions, assuming a fair sale, that both buyer and seller engaged in prudent actions and had sufficient knowledge, moreover, the meaning of market value implied that the ownership of property was transferred from the seller to the buyer on a particular date under several conditions as follows (Boyce 1984; Friedman et al. 2013):

- Both buyers and sellers are motivated to achieve a result.
- The provision of sufficient information, good advice, and that the best interests of both buyers and sellers are met.
- The property has been exposed to the open market for a reasonable time.
- Payment was made in cash, specifically in United States dollars.
- That it represented the normal consideration of property for the transaction.

The market value was also defined by the maximum price a buyer was willing to pay and the minimum price a seller was willing to accept (Friedman et al. 2013). Sohn et al. (2012) frame this slightly differently, contending that market value was the sum of the buyer's willingness to pay and the buyer's like or dislike of neighborhood features. In other words, the meaning of market value could be expressed in terms of either the transaction price or the actual sales price. According to the definition of market value, the Department of Taxation and Finance of New York State recommended the use of a sales comparison approach for estimating real estate market values. New York City's Department of Finance (NYC's DOF) estimated the worth of property in order to estimate the property's tax class and to meet New York State's legal requirements. The market value of property in NYC was the starting point for calculating the taxable value of a property, the assessed value, and the market value estimated by NYC's DOF utilized one of three approaches for each different tax class using annual actual property income and expense or a recent sales prices of comparable properties in the same neighborhood to approximate the actual market value as closely as possible. Therefore, the market value estimated by NYC's DOF should provide an adequate fundamental property value for calculating the assessed value, which equals the market value multiplied by the level of assessment, and the market value should be different from the assessed value in this research. (Almanzar 2012; NYC Department of Finance 2013a; 2013b). The market values estimated by DOF in NYC were based on recent sale prices, income and operating expenses, construction, replacement, or reproduction cost, or a combination of these factors. All properties in NYC were assigned to one of the tax classes, and a different approach was applied to each tax class because every property had a different purpose and different characteristics. Table 3.4 described the approach methods for each tax class.

Table 3.4. Tax Classes and approaches applied by New York City's Department of Finance

Tax Class	Approach	Descriptions
Class 1	Comparable sales approach	- 1-2-3 unit residential properties - Recent sales price of similar properties (size and location) - Properties sold in the neighborhood in the previous 3 years
Class 2	Income and expenses approach	- Residential property with more than 3 units (cooperatives and condominiums) - Income and expenses from comparable properties (land location, income level, building age and construction, and exemptions and subsidies-Only for "Large rental buildings) - Income based on the Gross Income from annual Real Property Income and Expense (RPIE) filings - Two methods for calculating market value; Net Income Capitalization and Gross Income Multiplier (GIM)
Class 3	Cost approach	- Utility property and special franchise property - Based on the value of land - The construction/reproduction/replacement cost of the building is added - Depreciation of the building value is taken into account
Class 4	Income and expenses approach	- Office buildings, factories, stores, hotels, and lofts - Income and expense based on annual Real Property Income and Expense (RPIE) reports from property owners

Note: Net Income Capitalization requires calculating net income, which is the difference between the income and expenses of a particular property, in advance and then net income divided by the capitalization rate that is the expected rate of return based on the income from a building. This method is usually applied to "Large condos and cooperatives" that have 11 units or more. Gross Income Multiplier uses the GIM ratio between the market value of a property and its future gross income. The total income of property is calculated by multiplying the typical income per sq-ft from comparable rental properties by the total sq-ft of the building. This method is applied to "Small buildings" that have 10 units or fewer.

From a realistic standpoint, a real transaction price or an actual sales price, if available, is the most valuable data that can be used to make the research more realistic. Cypher and Hansz (2003) concluded that experts who recognized the flaws of assessed value with regard to indicating an actual market value or a real transaction price considered that the assessed value had a limited validity, and Aydin et al. (2010) also insisted that data for actual sales prices should be preferred over tax appraisal data because this more accurately represented real market outcomes. The Harris County Appraisal District (HCAD) (2009) commented that some discrepancies between actual property prices and appraised values would be found. The Appraisal Institute (2002) gave two reasons why the relationship between assessed value and market value might have a restrictive correlation:

- Outdated mass valuations were generally used for estimating assessed values
- Assessed values might take into account fractional assessment ratios, partial exemptions, and other factors considered relevant by appraisers

Although Aydin et al. (2010) argued that the data of actual sales prices was a more accurate way to represent market outcomes, they went on to recommend that tax appraisals should be utilized for this type of research for the following reasons:

- The limited amount of data for actual sales prices was available during a typical research period. It was hard to explain price patterns statistically with very small sample sizes.
- A correlation between the actual sales and tax appraisal values was shown in their research. In their studies, not only was a county appraisal district in Texas, U.S. monitored regularly to meet the state's mandatory requirement that all appraisals were made at the market values, but the University of Houston found a correlation between actual sales value and tax appraisals in Texas counties. The strength of the correlation was quite high and, more importantly, spatially unbiased.

Zhang (2010) asserted that the tax base market value data offers a useful approximation to willingness to pay for a residential property because HCAD estimated the tax base market value of all residential properties every year, with a comparable sales approach. Dermisi (2009) agreed, suggesting four reasons for using assessor-generated property values (total assessed values and market values): 1) the difficulty in obtaining actual transaction prices of properties, 2) recently constructed buildings have little or no transaction history, and 3) the general lack of awareness of the economic benefits to be gained from LEED certification, and 4) ease of comparison with the results of later research using the same type of data, namely assessed property 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 research area, King County, Washington. Scanlon and Cohen concluded that "Whatever the particular technique, an income-based approach makes sense for income-producing commercial-residential property" (2009). Moreover, Cypher and Hansz (2003) also concluded that an assessed value treatment should be influenced upon the market value judgments to non-appraisers in the U.S. real estate market, and Kim and Son (2011) 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 in South Korea.

Other researchers have explained that the difficulty in using actual sales prices and real transaction prices comes from not only the limited number and the correlation of both prices and the limitation of their research scopes, but also the definition of market value. As mentioned earlier, they concluded that the primary decision factor for market value in an actual real estate market should be the willingness of buyer and seller, thus reflecting the realities of the real estate market in any research that focused on investigating the actual property value. Friedman et al. (2013) and Francis (2013) insisted that actual market value could only be decided by potential buyers and sellers based on their willingness to pay and it is often a struggle to find the meeting point of buyers' and sellers' expectations. This suggested that every pair of buyers and sellers had different expectations and viewpoints regarding their properties, so while some people might contend that the asking price was reasonable for a particular property, others could feel the asking price was higher than they would expect. NYC's DOF noted that market value could not be calculated precisely because the value was always estimated based on the best available information annually. However, they also mentioned that the market value was estimated by NYC's DOF very frequently to improve the accuracy of their market value and it was not directly based on calculating the property tax. Consequently, NYC's DOF estimated and used two values, market value and assessed value, when conducting the tax assessment exercise for all the properties in NYC, but the purpose and the meaning of these two values were different.

The market value of property in NYC was estimated every year. Two tax classes, Class 2 and Class 4, of property used the income and expense approach for calculating market value. Therefore when the market value was calculated each year, changes in building conditions had to be also considered because the average age of each building in NYC was about 68 years. This was high compared to other major cities in the world: it was 60 years in London, 20 years in Hong Kong, and 10 years in Shanghai (Blau 2012), although the useful life of a building was generally ranges from 30 to over 100 years (Pries and Janszen 1995; Pearce et al. 2012). The Mayor's Office of Long-Term Planning and Sustainability of NYC (2012) commented that most of the large buildings in the city were constructed from the 1920s to 1960s and that most multi-family buildings were built between 1910 and 1970. As a result, the range of building age in NYC, from 40 to 100 years old, could be almost the same as the useful life of a building.

Overall, the market value estimated by the DOF of NYC seemed to represent the property value reasonably well for all properties in NYC. It was consistently and transparently calculated and could be expected to reflect actual market value differences across properties. Moreover, the market value was produced and released annually to the public and sufficient market value is provided by NYC's DOF.

Establishing the property value of adjoining buildings of LEED and/or Energy Star certified office building utilizing the Hedonic Price Equation and Linear Mixed Effect Model.

The hedonic price model generally utilizes measures of social capital or the value of the environment based on cross sectional data for property values such as residential real estate prices or land prices. As a theoretical frame, the hedonic price model was based on empirical studies and had to be separated from non-environmental elements to include only the environmental elements when measuring the value of the environment using cross section data for land prices (Kanemoto 1997; Reichert 2002; Lee 2010). Based on this theoretical framework, Can (1992) pointed out that the hedonic price regression model was a common approach for measuring the neighborhood effect, encompassing characteristics of both the socio-economic and physical make-up of the area. Dunse and Jones (1998) also noted that hedonic regression analysis was widely used to evaluate the valuation of residential property in the United States, particularly in mass appraisals, and the technique had been also utilized in the United Kingdom to a limited extent. Kim and Son agreed, commenting that "The hedonic price model has useful functions when the research analyzes a heterogeneous market such as a real estate market, a labor market, an automobile market, and so on" (2011, p.198) while Lee et al. (2009) considered the hedonic price model to be a very useful methodology for understanding the effect of surrounding environmental conditions on the rental rates for office buildings.

As a result of this widespread agreement, the hedonic price model was utilized to measure the value of residential property in both the United States and the United Kingdom and researchers interested in property values of commercial property in the two countries generally applied the hedonic price model in their research (Hough and Kratz 1983 Fisher et al. 1994; Dunse and Jones 1998; Weinberger 2001; Chun et al. 2011). For instance, Chun et al. (2011) applied the hedonic price model to derive movements in commercial property values based on changes in the visible space by utilizing appraised total real estate taxes, which directly represented the commercial property values. To obtain a better determinant coefficient (R^2), there were four possible ways to transform the data sets in order to provide the most appropriate fit for the hedonic price model. Depending on the type of transformation of the data sets used for the response variable and explanatory variables, the hedonic price model suggested four different model equations, namely linear, log-linear, semi-log, and log-log, as follows:

- Linear function $p_i = a_0 + a_1 z_1 + \cdots\cdots + a_n z_n + \varepsilon_i$
- Log-linear function $p_i = a_0 + a_1 log(z_1) + \cdots\cdots + a_n log(z_n) + \varepsilon_i$
- Semi-log function $log(p_i) = a_0 + a_1 z_1 + a_2 z_2 + \cdots\cdots + a_n z_n + \varepsilon_i$
- Log-log function $log(p_i) = a_0 + a_1 log(z_1) + \cdots\cdots + a_n log(z_n) + \varepsilon_i$

Note. p_i: a value of response variable, a_p: coefficient, z_p: explanatory variables, ε_i: an error term, where i ={1,…,n} and n is the number of subjects in a data.

Used in isolation, the hedonic price model was not sufficient to analyze the full impact of a LEED or/and Energy Star certified office building on the unit market value of adjoining buildings over time because the model focused on a particular point of time for its analysis of the effect of external environmental factors or features on market values. For this reason, another methodology, linear mixed effect model, was also utilized for the current investigation of the changes in the market values of buildings in NYC that were located next to LEED and/or Energy Star certified office buildings over time. The linear mixed effect model included the fixed effects of explanatory variables for response as well as the random effects that vary depending on the subjects or the groups concerned. This statistical model was particularly useful for repeated measure data or cross-sectional studies in wide research disciplines (Song 1999; Starkweather 2010; Kang and Kim 2011; Seltman 2014). As each subject in the data provides multiple responses, these responses were correlated, which was explicitly forbidden by the assumption of standard ANOVA and regression models. Moreover utilizing linear mixed effect model made it possible to estimate the random intercept for each subject, control correlated data, and deal with unequal variances (SPSS 2005). Additionally, using a linear mixed effect model allowed the researchers to infer the primary interest by examining the fixed effects in this study. (Song 1999; Seltman 2014). The equation for linear mixed effect model is shown below.

$$y_{ij} = \beta_1 x_{1ij} + \beta_2 x_{2ij} \ldots \beta_p x_{pij} + b_{i1} z_{1ij} + b_{i2} z_{2ij} \ldots b_{iq} z_{qij} + \varepsilon_{ij}$$

Note. $\beta_{p:}$ Fixed effect coefficients, x_{pij}: Fixed effect variables for observation j in group i, b_{iq}: Random effect coefficients, z_{qij}: Random effect variables, ε_{ij}: the error for case j in group i

Problem Statement

Previous studies have examined the impact on the certified buildings themselves of LEED and/or Energy Star certification from an economic standpoint, reporting that the positive impacts achieved by one of both or both certifications could be measured in terms of the property values of the certified buildings through various economic measurements (McGraw-Hill Construction 2008; Miller et al. 2008; Eichholtz et al. 2010a; Dermisi and McDonald 2011; Fuerst and McAllister 2011). These studies have investigated ways of proving that LEED and/or Energy Star certification supports sustainability based on the economic benefits (in terms of the property values) gained by the certified building's stakeholders. However, the benefits gained by the buildings surrounding a LEED and/or Energy Star certified building, especially adjoining buildings in the neighborhood, have not been thoroughly researched. This research was therefore designed to measure the economic benefits afforded to buildings adjoining a LEED and/or Energy Star certified office building in terms of the impact on their market value. It serves as foundational research to help develop a better understanding of what is needed to accomplish a part of the triple bottom line of sustainability for both certifications. The research question guiding this study was, therefore: “What is the relationship between the attributes of LEED and/or Energy Star certified office buildings and the unit market value of buildings adjoining those certified office buildings in New York City?”.

Methodology

Definition of key terminologies

- Neighborhood

  A district or locality characterized by similar or compatible land uses and homogenous groupings. Neighborhood boundaries consist of well-defined natural or man-made barriers, land use changes or the characters of the inhabitants.

- Adjoining building

  A property located in the same neighborhood area which has similar external environmental conditions to the subject property and shares a common side zoning lot line with the subject property. In this research, the meaning of adjoining building is that a building is located in the same block as the LEED and/or Energy Star certified office building, and the building shares at least one common side zoning lot line between each building’s zoning lot boundaries. The term of adjoining building is referred to the Zoning Glossary[6] of NYC’s Department of City Planning (DCP).

[6] http://www.nyc.gov/html/dcp/html/zone/glossary.shtml

Research area and data sources

NYC is a particularly active region for establishing green buildings, including LEED certified buildings, Energy Star certified buildings, and other certified buildings. Recently, PlanNYC was launched to prepare the city to better suit the needs of its residents, encourage the local economy, address climate change issues, and improve the quality of life in NYC (The City of New York 2014). USGBC noted that the total area of LEED certified buildings began to increase from 2006 onwards, and has increased dramatically since 2009. Consequently, in 2012 NYC had the second highest number of LEED certified buildings, 491, of any metropolitan area in the U.S., with approximately 80 percent located in Manhattan as shown in the Green Building Information Gateway (GBIG) developed by USGBC, which provides a useful search engine platform for green building data and helps deliver new insights into this issue. GBIG also noted that NYC engages in a great number of green activities and has the most widespread achievement of Energy Star certification of any metropolitan area in the U.S. The number of Energy Star certified buildings continues to increase and NYC was ranked 4th among U.S. cities in 2012 in terms of the number of certified buildings according to the Energy Star website, which lists Energy Star Certified Buildings and Plants[7]. At present, almost 90 percent of the office buildings achieving LEED and/or Energy Star certification each year in NYC are located in Manhattan based on the information provided by the search tools, Energy Star Certified Buildings and Plants, and GBIG. NYC and Washington D.C. were identified as markets with good or better investment prospects in 2011, and NYC was the only metropolitan area which has been consistently identified as a good or better investment prospect in the real estate market since 2011 (Warren et al. 2013). Therefore, this research focused on the metropolitan area of NYC, specifically Manhattan.

Various data sources provided data sets for this research, each with a different format. The data gathered for each variable were summarized in Table 3.5. The most important issue was that each data source provides a different data set for the same building. For instance, the data set for LEED or Energy Star certification was provided through non-

[7] http://www.energystar.gov/index.cfm?fuseaction=labeled_buildings.locator

profit organizations and private commercial real estate information companies such as USGBC, Energy Star, CoStar, and Honest Building Solution, but the specific information related to achieving LEED or Energy Star certification differed slightly. It was necessary to secure the accuracy and consistency of data set from the data sources, so the data sets related to LEED and Energy Star certifications for this research were collected only from the USGBC and the EPA database operated and maintained by the official organizations of LEED and Energy Star. Note that this differed from the procedure followed in several previous studies reported in the literature, which used data on LEED or Energy Star certification provided by CoStar or other organizations. Additionally, the physical and geographic information for LEED and/or Energy Star certified office buildings contained some gaps across data providers; thus, the information on the physical building characteristics and geographical building location of LEED and/or Energy Star certified office buildings was collected solely from the database maintained by NYC's DCP associated with NYC's DOF. The data on market values based on the fiscal year (FY) for financial reports for selected certified office buildings and buildings adjoined to the certified office buildings from FY 2007 through FY 2015 were listed in NYC's DOF database, and the market value data was collected by downloading the data from FY 2009 through FY 2015 from their website[8] and submitting an application via the Freedom of Information Law (FOIL) for the data from FY 2007 through FY 2008. The fiscal year for the NYC's DOF was based on the 12 months from July 1 to June 30; FY 2013 therefore runs from July 1, 2012 to June 30, 2013. The GIS data for populating ArcGIS 10.1 were obtained from the website maintained by NYC's DCP and the Information Technology and Telecommunications Department (ITTD) of NYC; the most recent data were produced in October 2013.

It was important to note that as the data used in this study were collected by different organizations to suit their own needs, all the data sets had different measurement periods; the data set for market values provided by NYC's DOF ran from FY 2007 through FY 2015, that for the LEED characteristics of the certified office building in NYC provided

[8] http://www.nyc.gov/html/dof/html/property/assessment.shtml#roll

by USGBC ran from 2007 through 2013, and that of the Energy Star certified office buildings in NYC provided by EPA from 2003 through 2013. Therefore, the market value data for LEED and/or Energy Star certified office buildings and their adjoining buildings were selected from FY 2007 through FY 2013 as the market values could be calculated in terms of the reported property values between July 1, 2012 and June 30, 2013 provided by NYC's DOF.

Table 3.5. Measurements and critical data sources

	Variable name	Measurement description	Data source
Physical information of building	Building floors of LEED and/or Energy Star certified building	The number of floors	NYC's DCP
	Year built of LEED and/or Energy Star certified building	Completion date of an existing building (in Year)	NYC's DCP
	Floor Area Ratio (FAR) of LEED and/or Energy Star certified building	The ratio of the above-ground floor area of a building to the land area (Decimal)	NYC's DCP
	Class of LEED and/or Energy Star certified building	The quality of buildings depending on the building ages or the amount of amenities for building users	NYC's DCP
LEED information	LEED certification level	The level of LEED certification (Certified:1/Silver:2/Gold:3/Platinum:4)	USGBC
	LEED certification coverage	Certification of a whole building or a part of the building (Non:0/Partially:1/Fully:2)	USGBC
	LEED certified year	Certified year (Non-certified year:0/Certified year:1)	USGBC
	Unit market value of LEED only or LEED and Energy Star certified buildings per year (2007-2013)	Market value of property estimated by NYC's DOF from FY 2007 through FY 2013 (in dollars) is divided by the property area.	NYC's DOF
Energy Star information	Energy Star certified year	Energy Star certification is reevaluated annually. (Non-certified year:0/Certified year:1)	EPA
	Unit market value of Energy Star only or LEED and Energy Star certified buildings per year (2007-2013)	Market value of property estimated by NYC's DOF from FY 2007 through FY 2013 (in dollars) is divided by the property area.	NYC's DOF
Market value	Unit market value of adjoining buildings per year (2007-2013)	Market value of property estimated by NYC's DOF from FY 2007 through FY 2013 (in dollars) is divided by the property area.	NYC's DOF

Variables (Dependent variable/Independent variables)

Based on the previous literature, the measurements of the property value of adjoining buildings would be assigned as a dependent variable and other characteristics of the LEED and/or Energy Star certified buildings such as the LEED certification level and coverage, Energy Star certification renewal, building area, number of floors, building ages, etc. as independent variables in both the hedonic price model and linear mixed effect model. Table 3.6 described the variables and the data assigned to each variable.

Table 3.6. Research variables

<table>
<tr><th colspan="2">Variable</th><th>Measurement</th><th>Data measurement</th></tr>
<tr><td colspan="2">Dependent variable</td><td>Unit market value of adjoining buildings (2007-2013)</td><td>Continuous</td></tr>
<tr><td rowspan="11">Independent variable</td><td>Market value</td><td>Unit market value of LEED and/or Energy Star certified office building (2007-2013)</td><td>Continuous</td></tr>
<tr><td rowspan="3">Characteristics of LEED certification</td><td>LEED certification achievement</td><td>Categorical</td></tr>
<tr><td>LEED certification level (Certified/Silver/Gold/Platinum)</td><td>Categorical</td></tr>
<tr><td>LEED certification coverage (Non/Partial/Full)</td><td>Categorical</td></tr>
<tr><td rowspan="7">Building's physical characteristics</td><td>Energy Star certification achievement and renewal (Non-certified or no renewal/Certified or renewal)</td><td>Categorical</td></tr>
<tr><td>Floor Area Ratio (FAR)</td><td>Continuous</td></tr>
<tr><td>Building floors</td><td>Continuous</td></tr>
<tr><td>Year built</td><td>Categorical</td></tr>
<tr><td>Class of building</td><td>Categorical</td></tr>
<tr><td>LEED certified year</td><td>Categorical</td></tr>
<tr><td>Energy Star certified or renew year</td><td>Categorical</td></tr>
</table>

Defining the coverage and level of LEED certified office buildings that achieved multiple LEED certifications

Basically, an Energy Star certified building is required to renew its Energy Star certification annually by re-evaluating the results of its building performance during the certified year. In addition, Energy Star certification consists solely of either the achievement of Energy Star certification or no achievement of Energy Star certification. In contrast, it is not necessary to renew LEED certification since a building becomes a LEED certified building based on the results of building performance. Moreover, LEED certification can be expressed by two major characteristics of LEED certification, the coverage, i.e. whether the LEED certification is for the whole building or part of the building, and level, which can be one of four levels ranging from Certified through Platinum. This study included 12 LEED certified office buildings that had achieved multiple LEED certifications, in most cases raising the certification level over time. Table 3.7 shows the number of LEED certified office buildings based on the number of LEED certifications achieved.

Table 3.7. Number of LEED certified office building based on the number of LEED certification achievement

No. of LEED certification	Two LEED certifications	Three LEED certifications	Four LEED certifications
No. of LEED certified office building	10	1	1
Total No. of LEED certified office building with multiple LEED certifications	12		

This study therefore sought to re-define the coverage and level of LEED certified office buildings due to the achievement of additional LEED certifications. Based on the major characteristics of LEED certification, LEED certification for a whole building took precedence over LEED certification for part of building for the LEED certification coverage, and the highest level of LEED certification achieved, ranging from Certified, the lowest level of LEED certification, through Platinum, the highest, given priority when defining a building's LEED certification level for this study. For instance, a LEED certified office building that had achieved one LEED certification for the whole office building with a Gold level as its first LEED certification, and then subsequently achieved additional LEED certifications for part of the office building with two Platinum levels was treated as having achieved LEED certification for the whole building at the Gold level here, even though the office building had achieved two additional LEED certifications. Table 3.8 summarizes the list of 12 LEED certified office buildings that achieved more than one LEED certification and defines the coverage and level for each applied in this study.

Table 3.8. Summary of the changing LEED certification status of buildings

Change of LEED certification coverage	Change of LEED certification level	No. of LEED certified office buildings
Full/Full	Silver/Gold	1
	Certified/Gold	1
	Gold/Gold	1
Full/Partial	Silver/Gold	4
	Certified/Gold	1
Full/Partial/Partial	Gold/Platinum/Platinum	1
Partial/Full	Gold/Silver	2
Partial/Full/Partial/Partial	Silver/Gold/Platinum/Gold	1

Approach

This research utilized two different approaches: spatial and statistical analysis. GIS was used to identify the spatial distribution of LEED and/or Energy Star certified buildings and their adjoining buildings and to integrate all the information provided by various databases using a geographic map developed in ArcGIS 10.1. A statistical analysis was then performed to test the correlation between the independent variables and the dependent variable and determine the direction and strength of the correlations between each pair. The statistical analysis utilized R-Project 3.0.2. More detailed explanations of both these approaches are provided below.

- Geographical analysis approach

A geographical analysis was used to establish the geographic characteristics of LEED and/or Energy Star certified office buildings and their adjoining buildings and increase the accuracy of the geographic information for all buildings for this research. This approach was a fundamental process for the next statistical approach and consisted of the following tasks:

- Create a map containing location information for all the LEED and/or Energy Star certified office buildings and include other relevant features.

- Pinpoint the geographical location of LEED and/or Energy Star certified office building on a created map and comprehend the spatial distribution of LEED and/or Energy Star certified office buildings and their adjoining buildings.

- Construct the data sheet required for the statistical analysis by importing and matching all primary data sets based on the number of the Borough-Block-Lot (BBL).

- Export the integrated data sets to the next computational step, statistical analysis, using “R-Project 3.0.2”.

• Statistical analysis approach

A statistical analysis was used to identify the correlations between the independent variables and the dependent variable with numerical data sets through numerical results. This research utilized two statistical approaches, descriptive approach and regression approach, using “R-Project 3.0.2”. The regression approach applied two different regression models, the hedonic price model and the linear mixed effect model, which are complementary to minimize each model’s weak points. The results of this statistical approach indicated the strength and direction of the impact of LEED and/or Energy Star certified office buildings on the market values of adjoining buildings through the values of coefficients for each independent variable. The specific tasks of this statistical analysis approach were as shown below.

- Conduct two analyses: a descriptive analysis and regression analysis.

- Identify any correlation between the market value of each LEED and/or Energy Star certified office building and the market value of its adjoining buildings in NYC to demonstrate the socio-economic impact of LEED and/or Energy Star certification statistically.

- Analyze the data sets based on the hedonic price model and the linear mixed effect model using the ʹR-Projectʹ program for statistical computing.

- Identify all the coefficients needed to complete the linear mixed effect model equation based on the Hedonic Price Model Equations, and analyze the direction of the impact of LEED and/or Energy Star certification through these coefficients.

- Validate the numerical models of this study using Log-likelihood ratio statistics, which present the fitness of numerical models by comparing the fitted model and the null model.

Results

Geographical analysis result

The geographical analysis of the distribution of selected LEED and/or Energy Star certified office buildings in Manhattan NYC is depicted in Figure 3.1. As the figure shows, most of the LEED and/or Energy Star certified office buildings are located in the midtown area, with the remainder being located in the southwest area of Manhattan Island along the shoreline. Of these, 130 LEED and/or Energy Star certified office buildings in Manhattan NYC were selected as a screened population group based on evaluating the congruousness of the contents of the available data to maintain consistency in this research out of the total of 171 LEED and/or Energy Star certified office buildings in Manhattan NYC, identified by integrating the information provided by USGBC and EPA with the geographic information provided by the NYC's DCP. Note that each organization records slightly different information for LEED and/or Energy Star certified office buildings in their provided data. Therefore, the LEED and/or Energy Star certified office buildings in Manhattan were sorted and selected by matching the Borough-Block-Lot (BBL) number for the screened population group. Moreover, NYC's DOF provides the market value for individual units in multi-residential condominium buildings, rather than for an entire multi-residential condominium building, based on the ownership. Hence, those LEED and/or Energy Star certified office buildings with condominium buildings as one or more of their adjoining buildings were not selected for inclusion in the screened population. In addition, the LEED and/or Energy Star certified office buildings that did not have any adjoining buildings on the same block, occupying an entire city block by themselves, were excluded as they did not suit the purposes of this research. The selected LEED and/or Energy Star certified office buildings are shown in Figure 3.1 through Figure 3.3.

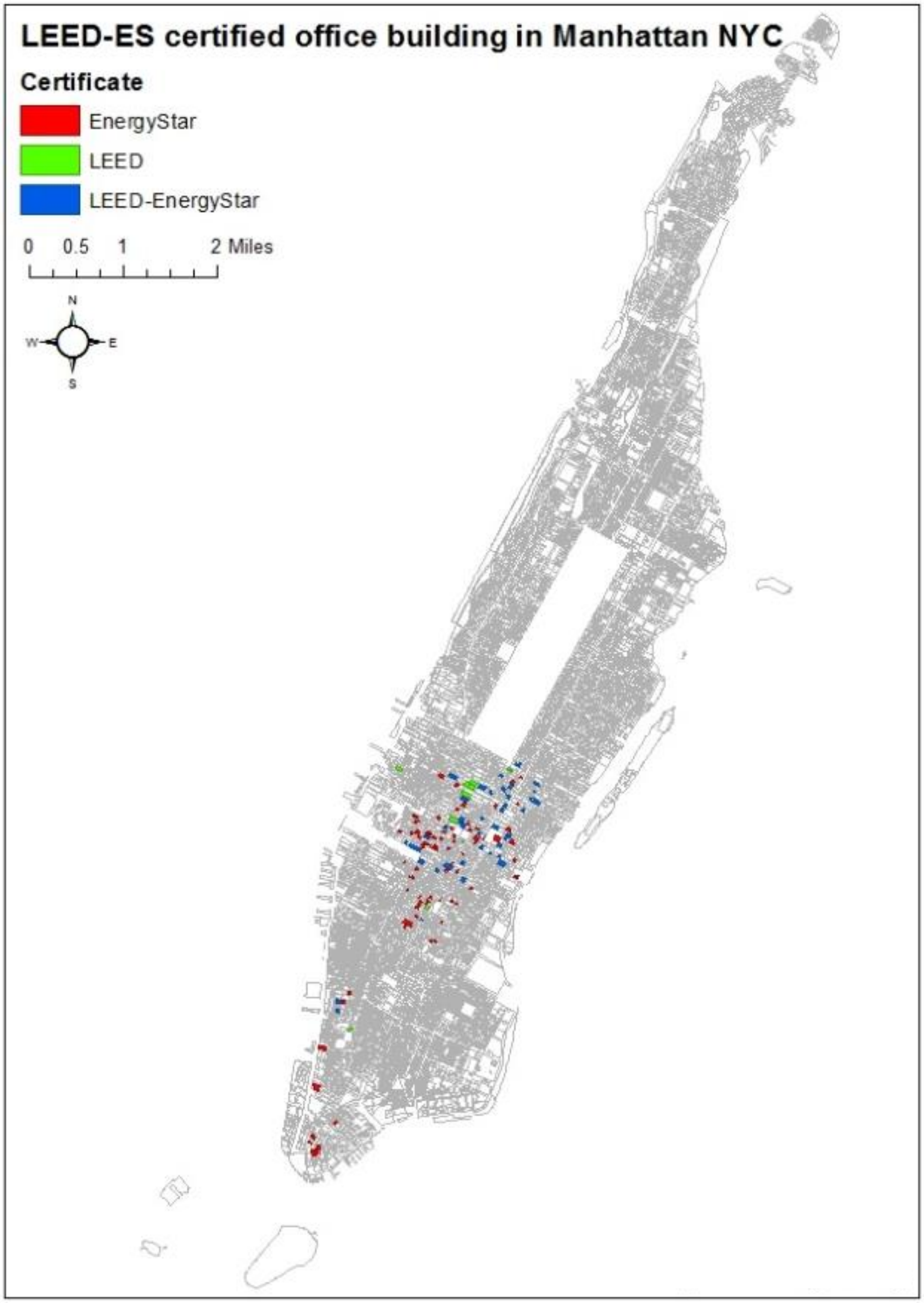


Figure 3.1. Overview of all the LEED and/or Energy Star certified office buildings in Manhattan NYC

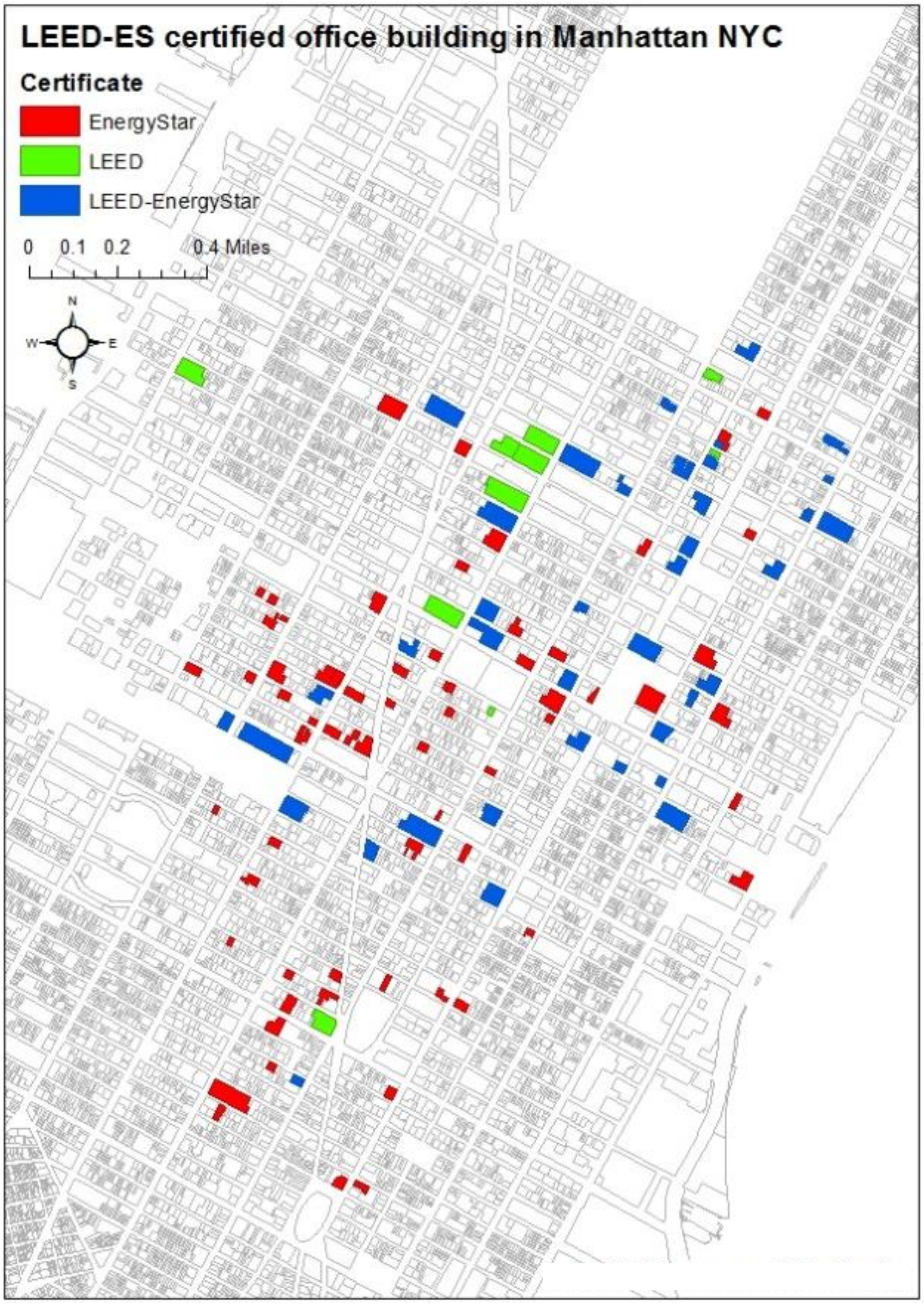


Figure 3.2. The LEED and/or Energy Star certified office buildings selected for this research (Midtown of Manhattan)

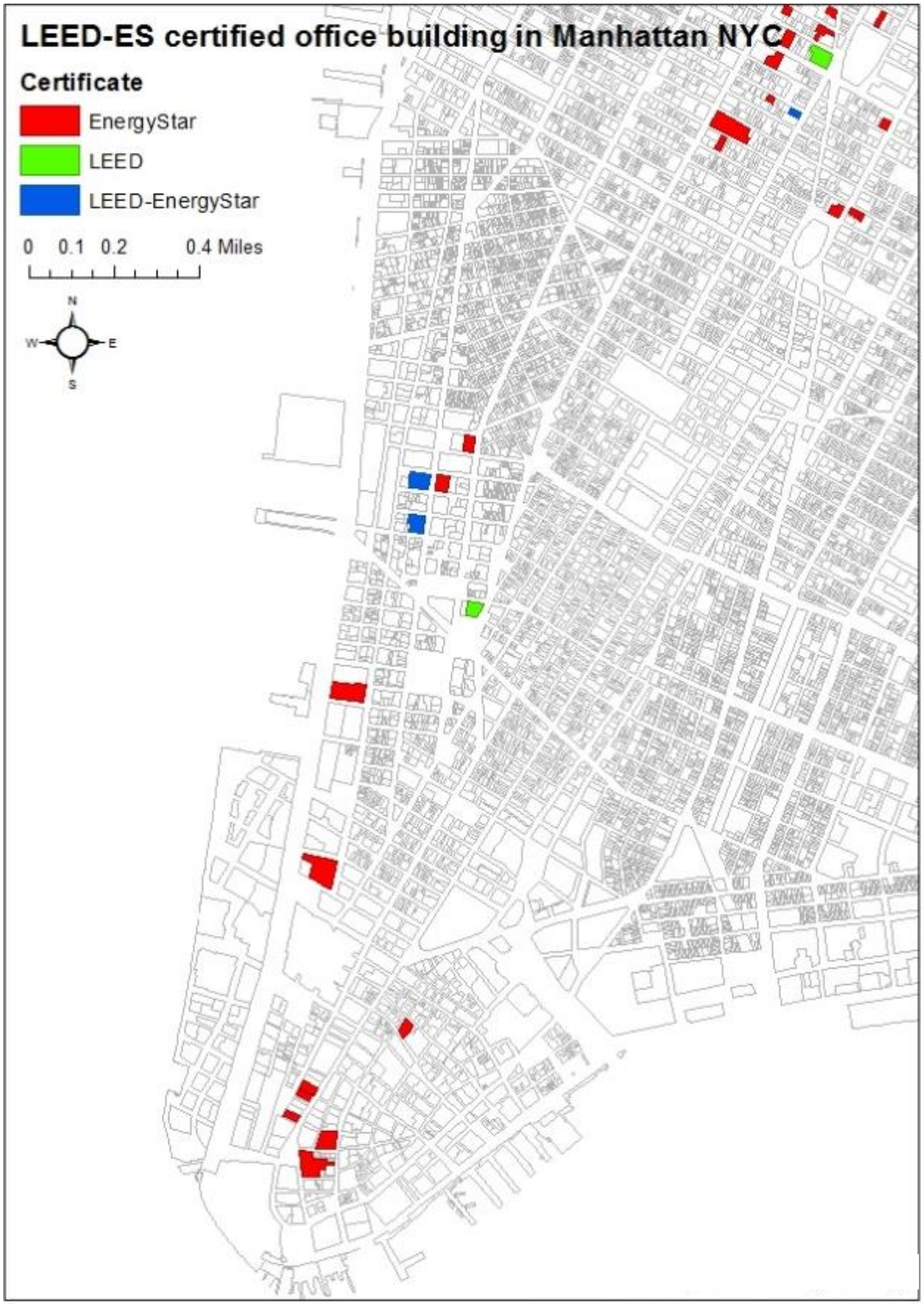


Figure 3.3. The LEED and/or Energy Star certified office buildings selected for this research (Southwest area of Manhattan)

The buildings adjoining the selected LEED and/or Energy Star certified office buildings were also included in the analysis using ArcGIS 10.1. The definition of adjoining used in this research follows the definition of NYC′s DCP, namely those properties sharing a common side zoning lot line with a LEED and/or Energy Star certified office building. Figure 3.4 shows how the adjoining buildings of LEED and/or Energy Star certified office buildings were identified. Note that buildings located across alleys or streets are not considered adjoining under this definition.

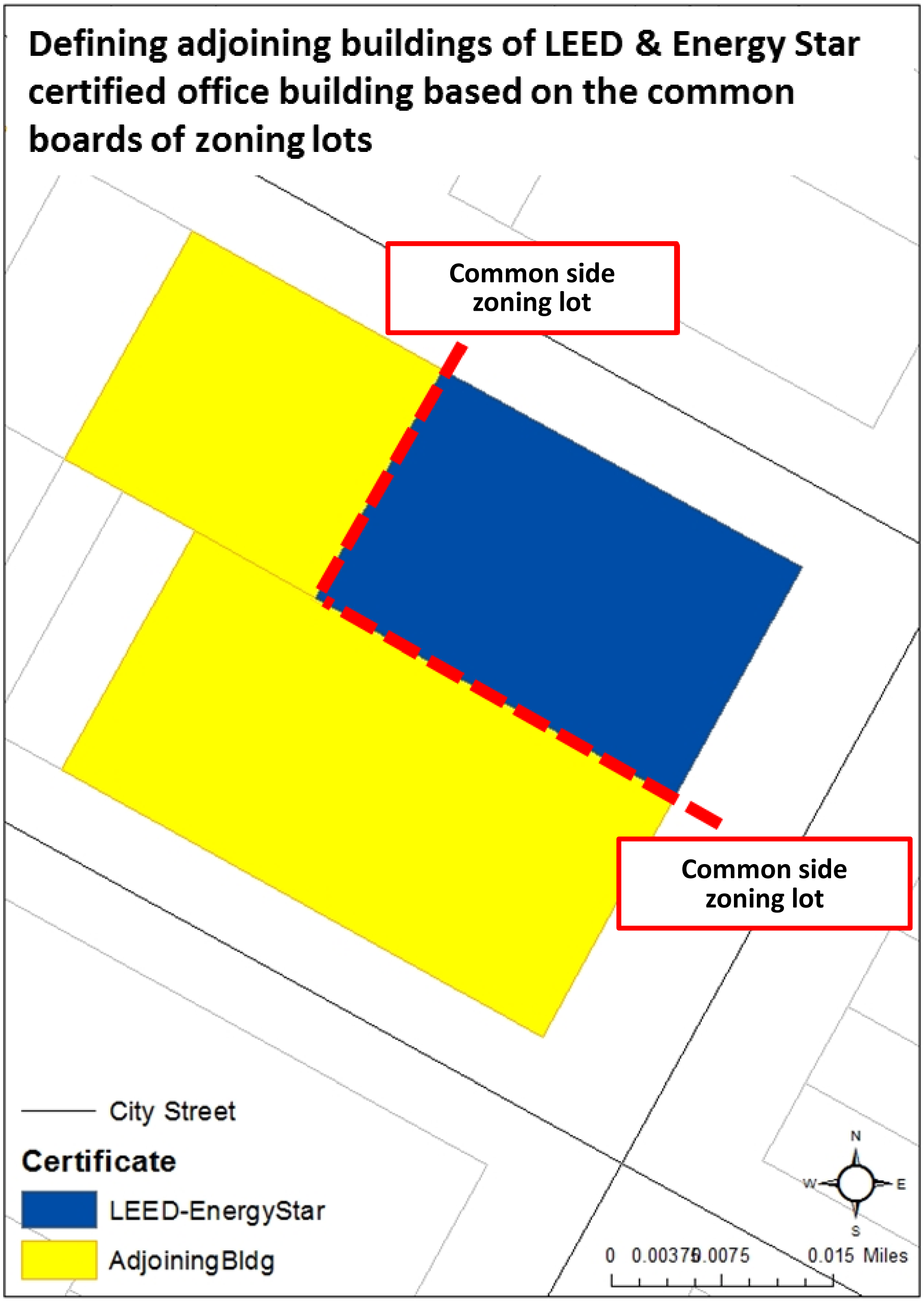


Figure 3.4. Sample showing the definition of adjoining building of a LEED and/or Energy Star certified office building

Based on this definition, 274 buildings were identified as adjoining the 130 LEED and/or Energy Star certified office buildings included in the study, and an overview of the number of LEED and/or Energy Star certified office buildings and their adjoining buildings is presented in Table 3.9. In particular, several of these 274 adjoining buildings had at least two LEED and/or Energy Star certified office buildings as a counterpart (Figure 3.5). Adjoining buildings with two or more counterparts were counted separately for each counterpart in this research. The numerical values assigned for the five different levels of LEED certification are shown in Table 3.9.

Table 3.9. Overview of number of LEED and/or Energy Star certified office buildings and their adjoining buildings

Certification	LEED only	Energy Star only	LEED and Energy Star
No. of certified office buildings	11	78	41
No. of adjoining buildings	20	160	94

Figure 3.5. Overlapping buildings adjoining Energy Star certified office buildings

In addition, there were five different types of LEED certification achievement, as shown in Table 3.10.

Table 3.10. Numerical values assigned for each LEED certification level

LEED certification level	No LEED	Certified	Silver	Gold	Platinum
Numerical value	0	1	2	3	4

As explained earlier, several of the LEED certified office buildings had achieved LEED certification more than once, and in some cases they had a different LEED certification coverage, either just part of the building or the whole building, for each certification (see Table 3.8). For instance, a building could achieve LEED certification at a particular certification level for a part of the building, and then achieve a different LEED certification at any level of LEED certification for the whole building, or a building could achieve a higher level of LEED certification than the previous level of LEED certification for the whole building. Twelve office buildings achieving LEED certification re-achieved LEED certification at least once, and one particular certified office building achieved LEED certification four times, either for a part of the building or the whole building during the research period. The determinant of LEED certification level for each LEED certified office building in each year applied here was based on the highest LEED certification level and the highest LEED certification coverage achieved, so the highest LEED certification level among the various levels achieved over time was utilized for each LEED certified office building and the LEED certification level for a whole building takes priority over the LEED certification level for a partial building over time, even if the partial building certification level was higher. For instance, a certain LEED certified building that achieved a Gold level for part of the building in 2011, and re-achieved the Silver level for the whole building the next year, 2012. In this case, the numerical value for the LEED certification level changed from three to two in 2012 because the new LEED certification level for the whole building, a Silver level, took priority over the previous LEED certification level covering just part of the building, a Gold level, even though the previous level was higher than the new level for this certified office building. In particular, two of the three certified office buildings achieved LEED certification twice, LEED Existing Building (EB) 2009, for a whole building without changing the version of LEED certification, but they enhanced the level of LEED certification for the latest LEED certification from Silver to Gold and Certified to Gold. In contrast, one of three certified office buildings reachieved LEED certification for the whole building to change the version of LEED certification from LEED EB 2.0 to LEED EB 2009 without enhancing the level of LEED certification from Gold to Gold. Additionally, the LEED certified office buildings tended to achieve the higher or same level of LEED certification for a part of building than the level of LEED certification for a whole building. The status of these changing LEED certifications and the definition of the coverage and level of LEED certified office building are summarized in Table 3.11.

Table 3.11. Summary of 12 LEED certified office buildings that achieved multiple LEED certifications and the definition of the coverage and level used for each in this study

LEED certifications (Coverage/Level)								Defining the coverage and level of LEED certified office building (Coverage/Level)
1st	Full/Certified	2nd	Partial/Gold	3rd	–	4th	–	Full/ Certified
1st	Full/Silver	2nd	Full/Gold	3rd	–	4th	–	Full/Gold
1st	Partial/Gold	2nd	Full/Silver	3rd	–	4th	–	Full/Silver
1st	Full/Certified	2nd	Full/Gold	3rd	–	4th	–	Full/Gold
1st	Full/Silver	2nd	Partial/Gold	3rd	–	4th	–	Full/Silver
1st	Full/Silver	2nd	Partial/Gold	3rd	–	4th	–	Full/Silver
1st	Full/Gold	2nd	Full/Gold	3rd	–	4th	–	Full/Gold
1st	Partial/Gold	2nd	Full/Silver	3rd	–	4th	–	Full/Silver
1st	Full/Silver	2nd	Partial/Gold	3rd	–	4th	–	Full/Silver
1st	FuDell/Silver	2nd	Partial/Gold	3rd	–	4th	–	Full/Silver
1st	Full/Gold	2nd	Partial/ Platinum	3rd	Partial/ Platinum	4th	–	Full/Gold
1st	Partial/Silver	2nd	Full/Gold	3rd	Partial/ Platinum	4th	Partial/ Platinum	Full/Gold

NYC′s DOF assessed the market value for a whole building or an individual unit in a building depending on the building type. For instance, the market value of a multi-residential condominium is estimated based on an individual unit in the adjoining building, as noted earlier. As a result, for this study unit market value was provided not for a whole building but only for individual units in each of the adjoining buildings. Moreover, the market value of each individual unit in an adjoining building required the individual house number, which was not easily obtained for each unit of each adjoining building. This research focused not the unit market value of individual unit, but on the unit market value of the building as a whole. Therefore, in order to include a multi-residential condominium, the unit market value of a multi-residential condominium would have had to be manually recalculated by considering the market value of each individual unit in the adjoining building. Due to the inherent difficulty of this process, these buildings were omitted from the group of buildings adjoining LEED and/or Energy Star certified office buildings to maintain the consistency of the market value data.

After compiling, the geographic information, the integrated data were exported to the Excel or CSV format for the statistical analysis using R-Project 3.0.2. Figure 3.6 presents an overview of the distribution of the buildings adjoining the selected LEED and/or Energy Star certified office buildings, and Figures 3.7 and 3.8 depict the distribution of the buildings adjoining the selected LEED and/or Energy Star certified office buildings in detail.

Figure 3.6. Distribution of buildings adjoining selected LEED and/or Energy Star certified office buildings in Manhattan, New York City (Overview)

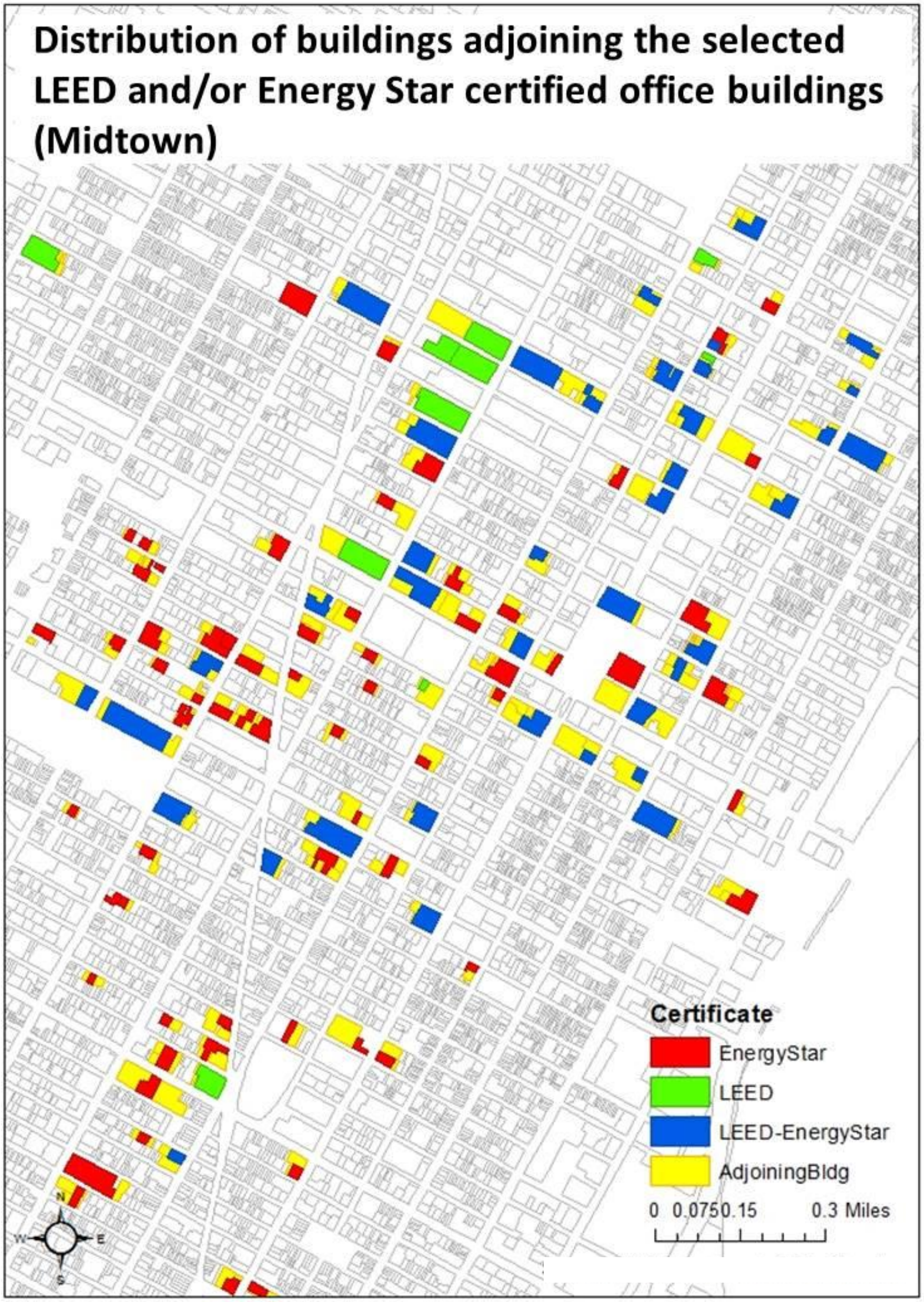


Figure 3.7. Buildings adjoining the selected LEED and/or Energy Star certified office buildings in this research (Midtown)

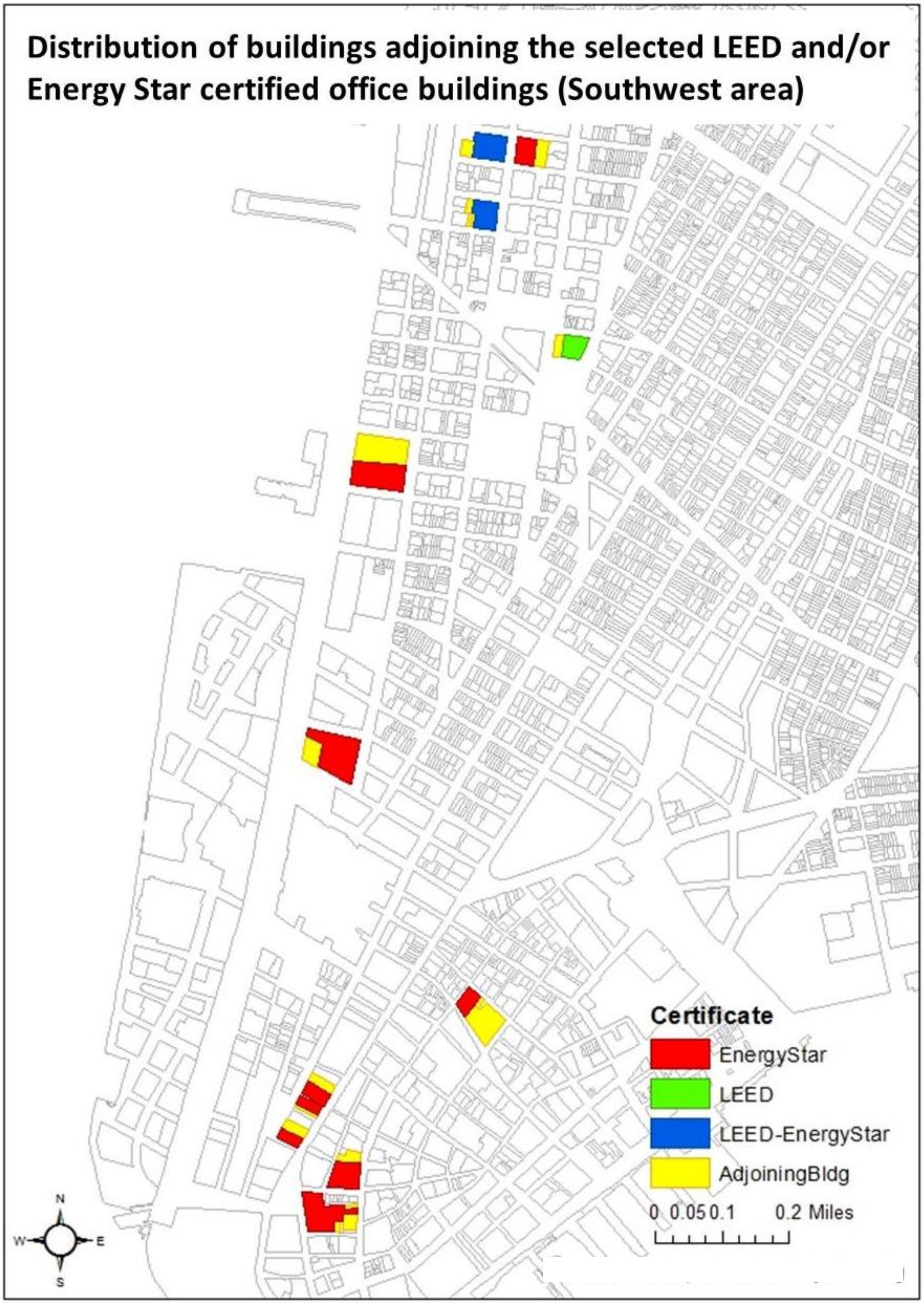


Figure 3.8. Buildings adjoining the selected LEED and/or Energy Star certified office buildings in this research (Southwest area)

Statistical analysis result

Based on the results of the geographical analysis and the exported data set, the number of LEED and/or Energy Star certified office buildings in Manhattan NYC included in the study was 130 and the number of adjoining buildings was 274. All information on dependent variable and independent variables was exported to the Excel format from ArcGIS 10.1 and subsequently imported to R-Project 3.0.2. The statistical analysis consisted of both a descriptive analysis and a regression analysis.

- Descriptive analysis

The descriptive analysis provided an overview of the information and described any trends in the data. For this research, data from five different tables was analyzed based on the characteristics of buildings shown in Table 3.12 to Table 3.16. Each table contained five measurements (minimum; maximum; median; mean; and standard deviation) for each year and showed the overall characteristics of the unit market value data. Unit market value was a key factor for this research because the correlation between LEED and/or Energy Star certified office buildings and their adjoining buildings focused on the unit market value.

In general, the data presented in each table indicated that the median unit market values for each year were lower than the mean market values, which meant that the shape of the data distribution was positively skewed, and the median value and the mean values increased over time. There was a tremendous difference between the minimum values and the maximum values for each year in all the tables. In particular, the difference in the unit market values of adjoining buildings showed the biggest gap, ranging from $725/sq-ft to $1,250/sq-ft, because various types of buildings were included in the dependent variable. At the same time, the difference in the unit market values of LEED and/or Energy Star certified office buildings for each year indicated only a small difference between the two values, although the median unit market value was bigger than the mean unit market value in 2011 for LEED only certified office buildings and in 2009 for Energy Star only certified office buildings. Moreover, the mean and the median unit market values for non-certified-years of the LEED and/or Energy Star certified office buildings also tended to exhibit similar differences with those for the same building once it achieved LEED and/or Energy Star certification.

Over the study period, the number of LEED only certified office buildings and Energy Star only certified office buildings tended to increase steadily, although in 2013 the number of Energy Star only certified office buildings actually decreased by 6. Energy Star certification required the energy performance to be reevaluated annually in order to renew and maintain the certification for the next year, and this requirement meant that 62 percent of the Energy Star certified office buildings in this study did not renew their certifications continuously since their first year of becoming Energy Star certified office building, either due to a failure to reevaluate the building energy performance as required or a decision not to renew by the building stakeholders.

Table 3.12. Descriptive summary of unit market values (dollars/sq-ft) of adjoining buildings

	Minimum	Maximum	Median	Mean	Standard deviation
2007	5.97	732.00	145.70	174.60	123.20
2008	5.42	826.70	161.30	207.60	150.67
2009	8.13	946.20	161.30	208.30	164.59
2010	8.13	875.00	164.20	211.60	155.70
2011	39.21	934.80	167.10	216.10	154.91
2012	59.85	1162.00	183.70	234.40	164.40
2013	48.32	1204.00	196.00	244.20	169.35

Table 3.13. Descriptive summary of unit market values (dollars/sq-ft) of LEED only certified-year buildings

	Number	Minimum	Maximum	Median	Mean	Standard deviation
2007	0	NA	NA	NA	NA	NA
2008	0	NA	NA	NA	NA	NA
2009	8	112.80	404.10	258.40	258.90	105.41
2010	18	83.00	557.20	251.10	264.80	118.42
2011	19	179.60	480.10	303.60	296.80	87.87
2012	22	175.60	555.70	305.40	317.40	102.77
2013	36	144.90	680.20	293.80	307.50	113.23

Table 3.14. Descriptive summary of unit market values (dollars/sq-ft) of Energy Star only certified-year buildings

	Number	Minimum	Maximum	Median	Mean	Standard deviation
2007	4	202.20	374.10	266.90	303.60	77.68
2008	17	87.38	385.70	179.60	241.80	88.17
2009	21	69.26	471.40	230.90	225.80	100.04
2010	23	64.63	468.10	212.90	221.50	107.87
2011	27	76.52	324.30	180.50	194.10	67.99
2012	49	78.58	512.50	193.60	210.30	87.18
2013	43	80.01.	418.60	198.40	208.60	87.36

Table 3.15. Descriptive summary of unit market values (dollars/sq-ft) of LEED and Energy Star only certified-year buildings

	Number	Minimum	Maximum	Median	Mean	Standard deviation
2007	0	NA	NA	NA	NA	NA
2008	0	NA	NA	NA	NA	NA
2009	3	226,60	443.90	289.50	320.00	118.80
2010	5	202.00	470.80	249.70	312.10	123.26
2011	13	149.20	412.70	226.90	254.30	89.78
2012	17	141.60	393.50	239.40	250.00	67.14
2013	16	202.40	632.50	269.60	330.70	144.68

Table 3.16. Descriptive summary of unit market values (dollars/sq-ft) of non-certified-year of LEED and/or Energy Star certified office buildings

	Number	Minimum	Maximum	Median	Mean	Standard deviation
2007	126	43.69	455.10	153.70	166.50	86.61
2008	113	53.52	494.50	161.20	175.10	87.40
2009	98	61.28	509.00	155.70	174.40	85.66
2010	84	58.72	519.40	158.60	175.20	83.33
2011	71	73.78	510.80	152.20	179.70	86.69
2012	42	83.51	525.40	172.40	200.70	99.69
2013	35	66.27	370.00	189.60	203.00	76.85

- Regression analysis

To initiate the regression analysis, it was first necessary to understand the correlation between the unit market value of LEED and/or Energy Star certified office building and the unit market value of its adjoining buildings. The correlations between the two unit market values for the certified office buildings and adjoining buildings over time indicated a linear correlation, as shown in Figure 3.9. Therefore, the regression analysis of this research consisted of the linear correlation models for further regression analysis.

Figure 3.9. Linear correlation between the unit market value of a LEED and/or Energy Star certified office building and those of buildings adjoining the certified office building (2007-2013)

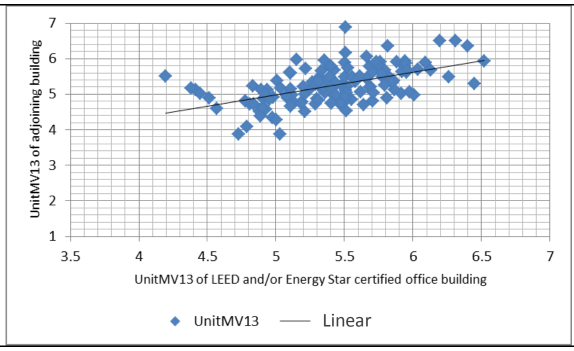
2013


Figure 3.9 (Continued). Linear correlation between the unit market value of a LEED and/or Energy Star certified office building and those of buildings adjoining the certified office building (2007-2013)

The unit market values of the buildings adjoining LEED and/or Energy Star certified office buildings were incorporated for FY 2007 through FY 2013 as a dependent variable, and several independent variables were applied to the regression model, namely the unit market value of the LEED and/or Energy Star certified office building, the achievement of LEED or Energy Star certification, the LEED certification level, the coverage of the LEED certification (either part of the building or the whole building), the number of floors, the building age, and the built floor-area ratio (FAR). In order to select the most appropriate linear equation model for this research based on the R^2 value, four different hedonic price model equations, Linear, Log-linear, Semi-log, and Log-log, were applied for every individual year from FY 2007 through FY 2013. The results revealed that the R^2 value for the Log-log graphs consistently produced the highest R^2 value for each research year. The R^2 values for each of four hedonic price model equations for 2010 are shown in Table 3.17 below as an example.

Table 3.17. R^2 values of four different hedonic price model equations in 2010

Transformation	Linear	Log-linear	Semi-log	Log-log
R^2 value	0.2274	0.3066	0.2284	0.3177
Adjusted R^2 value	0.203	0.285	0.205	0.297

The values of the correlation coefficients between the unit market values of adjoining buildings and the unit market values of LEED and/or Energy Star certified office building also suggested that the Log-log hedonic price model equation was the most suitable for this research because the value of the correlation coefficient for Log-log, 0.51, was higher than that for Linear, which was only 0.39. As a result, the further regression analysis conducted for this research supported a data transformation on the unit market values of LEED and/or Energy Star certified office buildings and their adjoining buildings. Therefore, the fundamental hedonic price model equation could be described as follows:

Formula: log(Unit market value of adjoining bldg.) = log(Unit market value of LEED and/or Energy Star certified office bldg.) + Bldg. class + Number of floors + Building ages + Built FAR + LEED certification achievement + LEED certification Level + LEED certification coverage + Energy Star certification achievement

In this case, the unit market value of LEED and/or Energy Star certified office building already took into account their building characteristics when appraised by NYC′s DOF; hence the variables related to building physical characteristics were eliminated for the next linear mixed effect model analysis to concentrate more on the variables of both LEED and Energy Star certifications.

For all these reasons, the linear mixed effect model used here was based on the Log-log hedonic price model equation and did not consider physical building characteristics such as building class, number of floors, building ages, or built floor-area ratio (FAR) when analyzing the correlation between the unit market values of the LEED and/or Energy Star certified office buildings and their adjoining buildings. The model was run with two unit market values transformed to log values. The regression analysis using the linear mixed effect model consisted of three top-down steps to evaluate the impact of LEED and/or Energy Star certified office buildings on the unit market value of adjoining buildings in this research, as shown below.

- Linear Mixed Effect Model for examining the effect of achieving LEED and/or Energy Star certification over time (from 2007 through 2013)
- Linear Mixed Effect Model for examining the effect of the level (Certified/Silver/Gold/Platinum) of LEED certification over time (from 2007

through 2013)

- Linear Mixed Effect Model examining for the effect of the coverage (Non/Partial/Full) of LEED certification over time (from 2007 through 2013)

1) Linear Mixed Effect Model for examining the effect of achieving LEED and/or Energy Star certification

The linear mixed effect model was applied to examine the effect of achieving LEED and/or Energy Star certification in order to analyze the effect of LEED and/or Energy Star certification on the unit market value of adjoining buildings after the subject building has achieved certification by investigating the strength of the impact and its direction. The model equation takes the following form:

Formula: log(Unit market value of adjoining building) = $\beta_0 + \beta_1$*log(Unit market value of LEED and/or Energy Star certified office building) +* $\beta_2 X_{LEED\ certification} + \beta_3 X_{Energy\ Star\ certification} + \alpha_0 + \alpha_1 b + \varepsilon$

Here, $X_{LEED\ certification}$ was the dependent variable (either 1, LEED certified, or 0, not LEED certified), $X_{Energy\ Star\ certification}$ was the dependent variable (either 1, Energy Star certified, or 0, not Energy Star certified), and *b* was the covariate for an individual building. In the model equation, the β_n's were the coefficients for fixed effects and the α_n's were the coefficients for random effects for buildings. This research focused specifically on the fixed effect on the unit market value of adjoining buildings. Based on the model equation, the results indicated that all the independent variables were statistically significant in this model because the P-values of both LEED and Energy Star certifications were lower than the significance level of 0.05, as shown in Table 3.16. Moreover, the effect of LEED and/or Energy Star certified office buildings on the market values of adjoining buildings appeared to have positive impact on the unit market values as these values played a role as the coefficient in the linear mixed effect model equation used to generate the data shown in Table 3.18.

Table 3.18. Result of linear mixed effect model for achieving LEED and/or Energy Star certification

	Estimated coefficient	P-value
Intercept	3.0465895	< 0.0001
Log(Unit market value of LEED and/or Energy Star certified office building)	0.4001741	< 0.0001
Energy Star certification achievement	0.0595213	0.0001
LEED certification achievement	0.0659072	0.0023

The fitted linear mixed effect model equation for this analysis was as follows:

log(Unit market value of adjoining building) = 3.0466 + 0.4002 X log(Unit market value of LEED and/or Energy Star certified office building) + 0.0595 X (LEED certification achievement) + 0.0659 X (Energy Star certification achievement) + $\alpha_0 + \alpha_1 b$,

where α_0 and α_1 are the estimated coefficients for the random effect of individual certified buildings, which are not presented here.

The resulting strength of the impact of the unit market value of a LEED and/or Energy Star certified office building on the dependent variable was shown in Table 3.19.

Table 3.19. Strengths of the impacts of the unit market values of a LEED and/or Energy Star certified office building

	Strength of impact
Unit market value of LEED and/or Energy Star certified office building	1.49212
Energy Star certification achievement	1.06133
LEED certification achievement	1.06812

These results indicated that as the unit market value of a LEED and/or Energy Star certified office building increased by $1/sq-ft, the unit market value of adjoining buildings increased by about 49 percent. In addition, when an office building achieved the Energy Star certification, the unit market value of adjoining building increased by 6 percent compared to the unit market value before its neighbor achieved Energy Star certification. The same was true of unit market value when the neighbor achieves LEED certification.

2) Linear Mixed Effect Model for examining the effect of LEED certification level

This linear mixed effect model analyzed the linear relationship between the various LEED certification levels and the unit market value of their adjoining buildings, so the independent variables were the unit market value of the LEED and/or Energy Star certified office buildings and the LEED certification level and the dependent variable was the unit market value of the adjoining buildings for this model. The model equation took the form shown below:

Formula: log(Unit market value of adjoining bldg.) = log(Unit market value of LEED and/or Energy Star certified office bldg.) + LEED certification level

This result confirmed that three of the four LEED certification levels, Certified, Silver, and Platinum, were significant for the dependent variable but one LEED certification level, Gold, was not significant because its significance level, 0.869, was over the significance level, 0.05. In addition, although the p-value of LEED Platinum certification was significant, the number of sample for the LEED Platinum level was too small to accept the estimated coefficient and the p-value as an effective result. Therefore, this result indicated that two levels of LEED certification did indeed have an impact on the unit market value of adjoining buildings, and those two LEED certification levels, Certified and Silver, had a positive effect on the unit market value of adjoining buildings. The fitted linear mixed effect model equation for this analysis was as follows:

log(Unit market value of adjoining building) = 2.7393 + 0.4624 X log(Unit market value of LEED only or LEED and Energy Star certified office building) + 0.1197 X (LEED Certified) + 0.0986 X (LEED Silver) + 0.0054 X (LEED Gold) − 0.8668 X (LEED Platinum) + $\alpha_0 + \alpha_1 b$,

where α_0 and α_1 are the estimated coefficients for the random effects of an individual certified building, which are not presented here.

Table 3.20 summarizes these values, indicating a linear relationship between the independent variables and the dependent variable.

Table 3.20. Summary of correlation values for the level of LEED certification achieved and the unit market value of certified buildings

	Estimated coefficient	P-value
Intercept	2.7393419	< 0.0001
Log(Unit market value of LEED and/or Energy Star certified office building)	0.4623754	< 0.0001
Certified level	0.1197142	0.0026
Silver level	0.0986043	0.0036
Gold level	0.0054277	0.8690
Platinum level	-0.8668129	< 0.0001

Consequently, the strengths of the impact of unit market value of LEED and/or Energy Star certified office building on the dependent variable is shown in Table 3.21.

Table 3.21. Strengths of the impacts of unit market value of LEED and/or Energy Star certified office building

	Strength of impact
Unit market value of LEED and/or Energy Star certified office building	1.58784
Certified level	1.12717
Silver level	1.10363
Gold level	1.00544
Platinum level	0.42029

When an office building achieved the Platinum level of LEED certification, the unit market value of adjoining building was reduced by 58 percent compared to the building without LEED certificate.

3) Linear Mixed Effect Model for examining the effect of LEED certification coverage

The correlation between the LEED certification coverage, either part of the building or the whole building, and the unit market value of adjoining buildings was studied using this linear mixed effect model, and the model equation took the following form:

Formula: log(Unit market value of adjoining bldg.) = log(Unit market value of LEED *and/or Energy Star certified office bldg.) + LEED certification coverage*

The dependent variable here was the unit market values of the building(s) adjoining LEED and/or Energy Star certified building on the log scale, and the independent variables were the unit market value of the LEED and/or Energy Star certified office building on the log scale and the LEED certification coverage, which was evaluated in terms of the numerical values shown in Table 3.22.

Table 3.22. Numerical values of LEED certification coverage for LEED and/or Energy Star certified office building

No LEED certification	LEED certification for part of the building (Partial LEED certification)	LEED certification for the whole building (Full LEED certification)
0	1	2

Consequently, the result of this analysis presented the effect of the level of LEED certification coverage on the dependent variable. LEED certification for only part of the building was not significant because the p-value was much higher than the reference value, 0.05. These results showed that there was no difference with respect to the unit market value of adjoining buildings when a building achieved partial LEED or a building had no LEED certification. The building that has achieved LEED certification for only part of the building actually had no significant difference on the unit market value of adjoining buildings, but a building that has achieved LEED certification for the whole building positively affected the unit market value of its adjoining buildings. The summary of this result is shown in Table 3.23.

Table 3.23. The impact of LEED certification coverage on the surrounding buildings

	Estimated coefficient	P-value
Intercept	2.8920720	< 0.0001
Log(Unit market value of LEED and/or Energy Star certified office building)	0.4328395	< 0.0001
Partial LEED certification coverage	-0.0516684	0.4870
Full LEED certification coverage	0.0744265	0.0008

As a result, the effect of LEED certification coverage on the unit market value of adjoining building was only positive if the LEED certification extended to the whole building. The fitted linear mixed effect model equation for this correlation was as follows:

log(Unit market value of adjoining building) = 2.892 + 0.4328 X log(Unit market value of LEED only or LEED and Energy Star certified office building) − 0.0517 X (Partial LEED certification) + 0.0744 X (Full LEED certification) + $\alpha_0 + \alpha_1 b$

where α_0 and α_1 are the estimated coefficients for the random effect of an individual certified building.

The resulting strength of the impact of the unit market value of a LEED and/or Energy Star certified office building on the dependent variable is shown in Table 3.24.

Table 3.24. Strengths of the impacts of unit market value of LEED and/or Energy Star certified office building

	Strength of impact
Unit market value of LEED and/or Energy Star certified office building	1.54163
Partial LEED certification coverage	0.94964
Full LEED certification coverage	1.07727

- Model validation

Three numerical fitted models were developed, one for each of the three independent variables; the model validation was based on each numerical fitted model and a null model. The model validation utilized the Log-likelihood Ratio Test (LRT), which compared the fitted model with the null model and indicated the fitness of the model through the numerical results, including the intercept and random effects for performing LRT. The null model indicated that the fitness of the fitted model decreased after adding additional variables to the fitted model, which includes an intercept. The hypotheses of LRT for the model validation in this study were as follows:

H_0*: The null model is true.*

H_1*: The null model is not true.*

1) Linear mixed effect model for the effect of the unit market value of LEED and/or Energy Star certified office building and the LEED and/or Energy Star certification

The dependent variable was the unit market value of the adjoining building(s) of the LEED and/or Energy Star certified office buildings and the independent variables were the unit market value of LEED and/or Energy Star certified office building, and the achievement of LEED certification and Energy Star certification in this linear mixed effect model for the seven year period from 2007 through 2013. All values of both variables were transformed by a natural logarithm. The test of model validation reported that the Log-likelihood ratio test (LRT) was 783.6022 with a significant p-value (p-value < 0.0001). The LRT test supported the fitted model rather than the null model. The results for the linear mixed effect model revealed that the values of AIC (Akaike Information Criterion) and BIC (Bayesian Information Criterion) for the fitted model were smaller than the equivalent values for the null model; thus, the linear mixed effect model for the data from 2007 through 2013 in this study should be statistically better than the null model.

2) Linear mixed effect model for the effect of the unit market value of LEED and/or Energy Star certified office building and the LEED certification level

The dependent variable of this model was the unit market value of adjoining building of LEED and/or Energy Star certified office building and the independent variables were the unit market value of LEED and/or Energy Star certified office building and the LEED certification level. All values of both variables were transformed by a natural logarithm. The LRT for validating this model reported the result of LRT was 261.5462, with a significant p-value smaller than 0.0001. Simultaneously, the values of AIC and BIC for the fitted model were smaller than the values of the null model. Therefore, this fitted model for the correlation between the dependent variable and two independent variables, the unit market value of LEED and/or Energy Star certified office building and the LEED certification level, was again statistically better than the null model.

3) Linear mixed effect model for the effect of the unit market value of LEED and/or Energy Star certified office building and the LEED certification coverage

The validation of the model for the effect of the unit market value of LEED and/or Energy Star certified office building and the LEED certification coverage on the unit market value of adjoining building of LEED and/or Energy Star certified office building revealed that all values of both variables were transformed by a natural logarithm. The result of LRT was 260.9993, and the p-value was significant because the p-value was once again smaller than 0.0001. At the same time, the values of AIC and BIC for this fitted model were smaller than the values for the null model. Consequently, this fitted model was deemed statistically better than the null model.

Discussion and Conclusions

This research focused on the effect of LEED and/or Energy Star certification on the unit market value of adjoining buildings in Manhattan, NYC. Here, the achievement of LEED and/or Energy Star certification and the characteristics of LEED certified office buildings were selected as the independent variable. In general, the results revealed that there was a correlation between LEED and/or Energy Star certification and the unit market value of adjoining building for the period from 2007 through 2013 from an economic standpoint. Moreover, the mere fact that a building has achieved LEED and/or Energy Star certification in most cases encouraged a positive change in the unit market value of adjoining buildings. While Energy Star certification was binary (either a building is certified or it is not), LEED certification had two major characteristics, coverage and level of certification, each of which had a different impact on the unit market value of adjoining buildings. LEED certification for the entire building and LEED Certified and Silver levels all had a positive impact on the unit market value of adjoining buildings, but the LEED Platinum level actually appeared to exert a negative impact on adjoining buildings. Furthermore, LEED certification for only part of a building and LEED Gold level were not significant as impact factors for adjoining buildings. These findings indicated that in general both the LEED and/or Energy Star certification had a positive impact on adjoining buildings. However, building stakeholders seeking to achieve the full benefits of LEED certification for their buildings should carefully consider the most appropriate LEED certification level and coverage needed to meet their goals. Their choices are also likely to positively influence sustainability as a result of the LEED and Energy Star certifications from an economic standpoint through providing the economic benefits that accrue to the buildings adjoining LEED and/or Energy Star certified office buildings.

To build on the outcome of this research, there remains scope for further research to overcome some of the inevitable limitations. First, this examination of the unit market values of adjoining buildings has provided only a limited window into the economic impact of LEED and/or Energy Star certified office buildings on today′s urban environment. It would be useful to consider a variety of types of LEED and/or Energy Star certified buildings, as well as more specific characteristics of LEED and Energy Star certification such as the change in LEED certification versions over time, instead of simply considering LEED and/or Energy Star certified office buildings in terms of two major characteristics of LEED certification as the independent variable and to expand the buildings considered to neighbor a LEED and/or Energy Star certified office building to cover particular areas to more broadly assess the economic impact through a wider representation of the neighborhood of the certified building. Second, the various external features in an existing environment such as access to a public transportation system, the public amenity facilities, and other types of public area exhibited various strengths and directions of impact depending on their proximity to a LEED and/or Energy Star certified office building, so a study quantifying changes in the strength of the impact of various economic indicators based on their proximity to a certified office building is likely to provide interesting results. Third, this study assumed that an adjoining building was independently affected by each adjoining LEED and/or Energy Star certified office building. This did not take into account the effect of multiple LEED and/or Energy Star certified office buildings on the unit market value of a single adjoining building. Lastly, this research focused not on predicting future market value variation of buildings adjoining LEED and/or Energy Star certified office buildings as a result of achieving certification, but instead on describing the effect of LEED and/or Energy Star certification on the unit market value of adjoining buildings as shown in the historical data. Thus, it would be necessary to consider various tangible and intangible characteristics of adjoining buildings to refine the outcomes of this research and build a useful predictive model in future research. A predictive model for changing property values due to the appearance or disappearance of external features in the existing environment, including LEED and Energy Star certifications, would help reduce the uncertainty of future property value fluctuations and improve strategic risk management in local real estate markets.

Although this research was subject to several limitations, its findings provide a good foundation and methodological approach for future research to investigate the impact of LEED and/or Energy Star certified office buildings on their neighboring buildings or neighborhood areas by considering the difference in the way the energy performance is assessed for LEED or Energy Star certification, namely in terms of the energy performance predicted or actual energy consumption, respectively. The research also provides useful guidance for the stakeholders of the LEED and/or Energy Star certified office building itself, as it focuses on a major component of their effort to achieve part of the triple bottom line of sustainability for LEED and Energy Star certification from an economic standpoint by encouraging and supporting mutual growth in the local real estate market.

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References

Almanzar Y. (2012). How does the city calculate property tax bills? The New York World:

Get inside your government. www.thenewyorkworld.com/2012/01/20/the-daily-q-how-does-the-city-calculate-property-tax-bills, (accessed November 12, 2013).

Appraisal Institute (2002). The Dictionary of Real Estate Appraisal, 4th Edition, Appraisal Institute, Chicago, IL.

Aydin, R., Crawford, E., and Smith, B. A. (2010). Commercial Development Spillover Effects Upon Residential Values, Southwestern Economic Review, http://www.ser.tcu.edu/2010/SER2010-Aydin-et-al-47-62.pdf, (August, 30, 2013).

Blau, R. (2012). Bloomberg is fast-tracking a plan to knock down obsolete buildings near Grand Central, New York Daily News. http://www.nydailynews.com/news/bloomberg-fast-tracking-plan-knock-obsolete-buildings-grand-central-article-1.1062335, (accessed November 5, 2013).

Bloom, G. F., Weimer, A. M., Fisher, J. D. (1982). Real Estate, 8th Ed., John Wiley & Sons, New York.

Booz Allen Hamilton (2008). Green Jobs Study, http://www.usgbc.org/ShowFile.aspx?DocumentID=6435, (accessed March 10, 2012).

Boyce, B. N. (1984). Real Estate Appraisal Terminology, Ballinger Publishing Company, Cambridge, MA.

Can, A. (1992). Specification and estimation of hedonic housing price models, *Journal of Regional Science and Urban Economics*, 22, 453-474.

Chang, K., and Chou, P. (2010). Measuring the influence of the greening design of the building environment on the urban real estate market in Taiwan, *Journal of Building and Environment,* 4S, 2057-2067.

Chun, B., Guldmann, J. M., and Seo, W. (2011). Impact of Multi-dimensional Isovist on Commercial Real Estate Values in CBD Area Using GIS, *Journal of Seoul Studies*, 12(3), 17-32.

Cypher, M. L., and Hansz, J. A. (2003). Does assessed value influence market value judgments? *Journal of Property Research*, 20(4), 305-318.

Dermisi, S. (2009). Effect of LEED Ratings and Levels on Office Property Assessed and Market Values, *Journal of Sustainable Real Estate*, 1(1), 23-47.

Dermisi, S., and McDonald, J. (2011). Effect of Green Designation on Prices/sf and

Transaction Frequency: The Chicago Office Market. *Journal of Real Estate Portfolio Management*, 17(1), 39-52.

Dunse, N., and Jones, C. (1998). A hedonic price model of office rents, *Journal of Property Valuation and Investment*, 16(3), 297-312.

Eichholtz, P., Kok, N., and Quigley, J. M. (2010a). Doing Well by Doing Good? Green Office Buildings, *American Economic Review*, 100(5), 2492-2509.

Eichholtz, P., Kok, N., and Quigley, J. M. (2010b). The Economics of Green Building, Working Papers, Berkeley Program on Housing and Urban Policy, Institute of Business and Economic Research, UC Berkeley.

Epley, D. R., and Rabianski, J. (1981). Principles of real estate decisions, Addison-Wesley Publishing Company, Inc., Philippines.

Eply, D. R., Rabianski, J. S., and Haney, R. L. JR. (2002). Real Estate Decisions, Thomson Learning, Cincinnati, Ohio.

Fisher, J. D., Geltner, D. M., and Webb, B. R. (1994). Value Indices of Commercial Real Estate: A Comparison of Index Construction Methods, *Journal of Real Estate Finance and Economics*, 9, 137-164.

Fowler, K. M. and Rauch, E. M. (2006). *Sustainable Building Rating Systems Summary*, The Pacific Northwest National Laboratory, PNNL-15858.

Francis, K. A. (2013). Market Value vs. Appraised Value http://smallbusiness.chron.com/market-value-vs-appraised-value-1023.html, (accessed November 2, 2013).

Friedman, J. P., Harris, J. C., and Lindeman J. B. (2013). Dictionary of Real Estate Terms, Barron’s Educational Series, Inc. Hauppauge, NY.

Fuerst, F., and McAllister, P. (2011). Green Noise or Green Value? Measuring the Effects of Environmental Certification on Office Values, *Journal of Real Estate Economics*, 39(1), 45-69.

Harris County Appraisal District (2009). Guide to understanding the property tax process. http://www.hcad.org/Help/Process/Guide.asp, (accessed November 2, 2013).

Herkel, S., Lӧhnert, G., Voss, K., and Wagner, A. (2004). Energy Efficiency in Commercial Buildings - Experiences and Results from the German funding Program

SolarBau, Proceeding of the 4th International Conference for Enhanced Building Operations, October 18-19, Paris, France.

Hough, D. E., and Kratz, C. G. (1983). Can “Good” Architecture Meet the Market Test?, *Journal of Urban Economics*, 14, 40-54.

Hui, E. C. M., Chau, C. K., and Law, M. Y. (2007). Measuring the neighboring and environmental effects on residential property value: Using spatial weighting matrix, *Journal of Building and Environment*, 42, 2333-2343.

Kanemoto, Y. (1997). Measurement of Development Benefits and the Hedonic Approach, Socioeconomic Evaluation of Road Investment Projects, 120-131, Keizai Inc, Tokyo, Japan.

Kang, K. and Kim, S. (2011). Analysis of the Elasticity of Loss Amount by Accident Types using Linear Mixed Effect Model, *Journal of Korea Insurance Research*, 22(1), 3-32.

Kerstens, S. M., De Ridder, R., Hof, A., Alberts, J., Mulhall, D., and Dale, D. (2011). Towards eco effective sustainable sanitation for the city of Almere, *Journal of Water Practice and Technology*, 6(2).

Kim, K. and Son, J. (2011). Real Estate Economics, KU Smart Press, Seoul, South Korea.

Kok, N., McGraw, M., and Quigley, J. M. (2011). The Diffusion of Energy Efficiency in Building, *American Economic Review*, 101(2).

Lee, J. (2010). Environmental economics, Pakyoungsa Publishing, Seoul, South Korea.

Lee, S., Lee, H., Son, J., and Choi, J. (2009). Developing Office Rent Model by Time-Series Analysis, *Journal of the Korea Real Estate Analysts Association*, 15(3), 5-17.

Lin, Z., Rosenblatt. E.. and Yao, V. W. (2009). Spillover Effects of Foreclosures on Neighborhood Property Values, *Journal of Real Estate Finance and Economics*, 38(4), 387-407.

Mansfield, S., Pattanayak, S. K., McDow, W., McDonald, R., and Halpin, P. (2005). Shades of Green: Measuring the value of urban forests in the housing market, *Journal of Forest Economics*, 11, 177-199.

Matthews, J. W. (2006). The Effect of Proximity to Commercial Uses on Residential Prices, Dissertation, Georgia State University and the Georgia Institute of Technology.

Mayor's Office of Long-Term Planning and Sustainability (2012). New York City Local Law 84 Benchmarking Report. http://www.nyc.gov/html/gbee/downloads/pdf/nyc_ll84_benchmarking_report_2012.pdf, (accessed November 12, 2013).

McGraw-Hill Construction (2008). Global Green Building Trends – Market Growth and Perspectives from Around the World, Smart Market Report: Design and construction intelligence, McGraw-Hill Construction, New York.

McGraw-Hill Construction. (2010). Green Outlook 2011 - Green Trends Driving Growth, McGraw-Hill Construction, New York.

Miller, N., Spivey, J., and Florance, A. (2008). Does Green Pay Off?, *Journal of Real Estate Portfolio Management*, 14(4), 385-398.

Muldavin, S. R. (2010). Value Beyond Cost Saving: How to Underwrite Sustainable Properties, The Muldavin Company, Inc. ISBN 978-0-9826357-0-4.

New York City Department of Finance (2014), Determining Your Market Value: http://www.nyc.gov/html/dof/html/property/property_val_estimate.shtml (accessed October 21, 2013).

New York City Department of Finance (2013a). NYC Residential Property Taxes: Class One – One, Two, Three, Family Homes, http://www.nyc.gov/html/dof/downloads/pdf/brochures/class_1_guide.pdf, (accessed October 31, 2013).

New York City Department of Finance (2013b). NYC Residential Property Taxes: Class Two – Coops Condos Rentals 4+ units, http://www.nyc.gov/html/dof/downloads/pdf/brochures/class_2_guide.pdf, (accessed October 31, 2013).

Pearce, A. R., Ahn, Y. H., and HanmiGlobal (2012). Sustainable buildings and infrastructure paths to the future, Routledge, New York.

Pries, F., and Janszen, F. (1995). Innovation in the construction: the dominant role of the environment, *Construction Management and Economics* 13, 43-51.

Reichert, A. K. (2002). Hedonic Modeling in Real Estate Appraisal: The case of Environmental Damages Assessment, Real Estate Valuation Theory, Kluwer Academic, Boston.

Ries, R., Bilec, M. M., Gokhan, N. M., and Needy, K. L. (2006). The Economic Benefits of Green Buildings: A Comprehensive Case Study, *The Engineering Economist*, 51(3), 259-295.

Rood, T. (2000) Ped Sheds. San Francisco, CA: Congress of the New Urbanism.

Saphores, J., and Li, W. (2012). Estimating the value of urban green areas: A hedonic pricing analysis of the single family housing market in Los Angeles, CA, *Journal of Landscape and Urban Planning* 104, 373-387.

Scofield J. H. (2009). A Re-examination of the NBI LEED Building Energy Consumption Study, 2009 Energy Program Evaluation Conference, Portland, OR.

Seltman H. J. (2014) Experimental Desing and Aanlysis, Chapter 15 Mixed Model, 357-378, http://www.stat.cmu.edu/~hseltman/309/Book/chapter15.pdf, (accessed March 24, 2014).

Sohn, D. W., Moudon, A. V., and Lee, J. (2012). The economic value of walkable neighborhoods, *Urban Design International*, 17(2), 115-128.

Song, K. (1999). The Study of Random Effects in Linear Mixed Model for the Analysis of Repeated Measures, Dissertation, Yonsei University, South Korea.

Spreckley, F. (1981). Social Audit: A Management Tool for Co-operative Working 1981, Beechwood College Ltd., Leeds, United Kingdom.

SPSS Inc. (2005). Linear Mixed-Effects Modeling in SPSS: An Introduction to the MIXED Procedure, Technical Report LMEMWP-0305.

Starkweather, J. (2010). Linear Mixed Effects Modeling using R, http://www.unt.edu/rss/class/Jon/Benchmarks/LinearMixedModels_JDS_Dec2010.pdf, (accessed March 23, 2014).

Suh, M., Pearce, A. R., and Kwak, Y. (2013). The effect of LEED certified building on the neighborhood market value in New York City, The 5th International Conference on Construction Engineering and Project Management, Jan 9-11, Anaheim, CA, USA.

The City of New York (2014). PlaNYC website: http://www.nyc.gov/html/planyc/html/about/about.shtml, (accessed November 31, 2013).

Tax Commission of The City of New York (2013). How to appeal a tentative assessment: http://www.nyc.gov/html/taxcomm/downloads/pdf/tc600.pdf, (accessed November 1, 2013).

The Secretariat of the Commission for Environmental Cooperation (2008). Green Building in North America: Opportunities and Challenges, Commission for Environmental Cooperation, Montreal, Canada, ISBN 2-923358-47-3.

U.S. Department of Energy (2008). Energy Efficiency Trends in Residential and Commercial Buildings. http://apps1.eere.energy.gov/buildings/publications/pdfs/corporate/bt_stateindustry.pdf, (accessed November 22, 2013).

U.S. Environmental Protection Agency (2006). Summary of The Financial Benefits of Energy Star Labeled Office Buildings, EPA 430-S-06-003.

U.S. Environmental Protection Agency (2012). Top Cities with the Most Energy Star Certified Buildings in 2012. http://www.energystar.gov/sites/default/uploads/buildings/old/files/Top_cities_chart.pdf, (accessed November 30, 2013).

U.S. Environmental Protection Agency (2013). Energy Star Overview of 2012 Achievements, http://www.energystar.gov/ia/partners/publications/pubdocs/ES%20bi-fold%20031313%20FINAL%20for%20print%20rev.pdf?b5fb-2f46, (accessed August 20, 2013).

Weinberger, R. R. (2001). Commercial property value and proximity to light rail: A Hedonic Price Application. Dissertation, University of California Berkeley, CA.

Wiley, J. A., Benefield J. A., and Johnson K. H. (2010). Green Design and the Market for Commercial Office Space. *Journal of Real Estate Finance & Economics*, 41(2), 228–243.

Yu, S., Tu, Y., and Luo, C. (2011). Green Retrofitting Costs and Benefits: A New Research Agenda, Institute Real Estate Studies Working Paper Series, the Department of Real Estate, National University of Singapore, Singapore.

Zhang, Y. (2010). Residential Housing Choice in a Multihazard Environment: Implications for Natural Hazards Mitigation and Community Environmental Justice, *Journal of Planning Education and Research*, 30(2), 117-131.

Chapter 4

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

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This paper will be submitted to the *Journal of International Real Estate and Construction Studies* (XXXX 2015).

Abstract: Green building certifications are being adopted more widely, and existing research continues to show an array of benefits to stakeholders of buildings pursuing certification, including energy and water savings as well as other less tangible benefits. However, little attention has been paid thus far to the effects these buildings may have on their surrounding neighborhoods. Several researchers have been seeking to quantify the economic or environmental benefits to society gained via these green building certifications to satisfy a part of the triple bottom lines of sustainability for LEED and Energy Star certifications. 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. The results of this study showed

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that the unit market value of LEED and/or Energy Star certified office buildings, the achievement of LEED and/or Energy Star certification, LEED certification coverage, and LEED certification levels except Platinum had a positive impact on the median unit market value of their neighborhood areas based on the definition of walkable distance. The findings can also provide useful insights into the possibilities afforded by LEED and/or Energy Star certification for additional economic benefits, encouraging a win-win approach that enhances the local real estate market.

Introduction

Sustainability is becoming a major issue in various fields. Interest in sustainability is no longer limited to social scientists and economists but is now also attracting attention from engineers and environmental scientists. Green building certifications provide a useful tool for those leading efforts to focus on environmental aspects of the building life cycle such as minimizing environmental contamination and natural resource depletion. The purpose of green building certifications is changing to support efforts to achieve sustainability because the needs of building stakeholders are also expanding from a simple focus on better energy and water performance to obtaining a better quality of life from a number of different perspectives. In particular, both the environmental and economic benefits to be gained through the Leadership in Energy and Environmental Design (LEED) and the Energy Star certifications, the two leading green building certifications in the United States, for a certified building have been investigated by a number of researchers (USEPA 2006; 2013; Booz Allen Hamilton 2008; Miller et al. 2008; Scofield 2009b; and Suh et al. 2013). However, little research has yet been undertaken to examine the economic benefits of LEED and Energy Star certification for the surrounding neighborhood or local community from a real estate perspective. To ensure the sustainability of green building certification, it is necessary to meet the triple bottom lines of sustainability, namely its environmental, economic, and social aspects (Spreckley 1981). This concept has recently been updated by Kerstens et al. (2011), and Suh et al. (2013) who suggested the principle of the ‘3Ps’, namely People, Planet, and Profit, that had to be involved in order to implement sustainability. Suh et al. (2013)

described these 3Ps using the concept of the living machine from Korean traditional living culture, as shown in Figure 4.1.

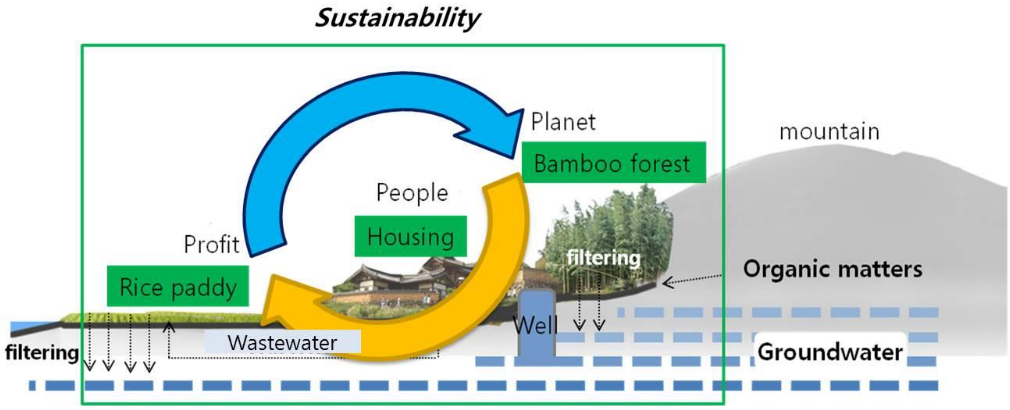

Figure 4.1. Principle of the 3Ps (adapted from Suh et al. 2013)

Based on the principle of the 3Ps, this research focused primarily on the 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 for promoting the local real estate market and the community. This research is expected to expand the concept of "green" beyond simple environmental performance to include critical economic factors, in this case unit market value, by examining their impact from a fresh perspective and thus initiating a more comprehensive investigation of the two 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 both the diffusion and the sustainability of the LEED and Energy Star certifications by encouraging building stakeholders, neighbors, and federal and local governments to appreciate the economic opportunities and benefits of LEED or Energy Star certification and the fresh perspective it offers for addressing issues related to economic revitalization for the local real estate market and local community. In particular, this research provides useful information to support the decision making processes of neighbors in the local community and local government agencies related to sustaining and diffusing LEED and Energy Star certification schemes from both the economic and environmental standpoints. Figure 4.2, developed from Suh et. al. (2013) depicts the expectations of each building stakeholder from this research.

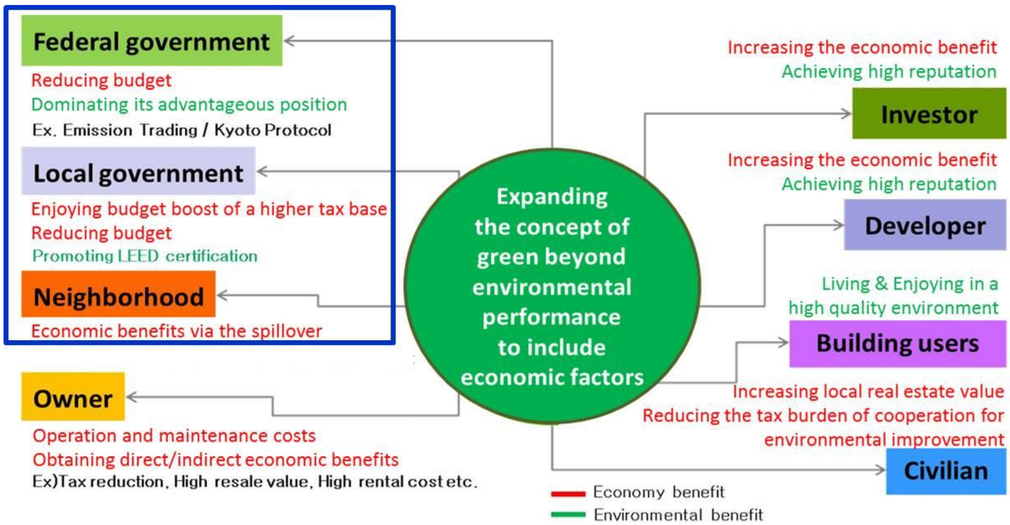

Figure 4.2. Expanding the concept of green beyond environmental performance (adapted from Suh et al. 2013)

Background

The impact on the property value of a building with various external features in the existing environment

In general, the property values are determined by the interaction of suppliers and buyers in the real estate market which is referred to as the law of supply and demand (O'Donnell and Maleady 1975; Epley et al. 2002; O'Sullivan 2009). The property value of a particular building is affected by the real property commodity itself and the external environmental features in which it was located. 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 (Epley and Rabianski 1981; Bloom et al. 1982; Epley et al 2002). Therefore, the property value of every building is affected by a number of external environmental features, which might be either tangible or intangible, in the existing environment.

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 various environmental features. Nelson (1980), Weinberger (2001), Kim et al. (2003), Mansfield et al. (2005), Hui et al. (2007), Lin et al. (2009), Liu et al. (2010), Chang and Chou (2010), Chun et al. (2011), Saphores and Li (2012), and Suh et al. (2013) have investigated the correlation between the property values of properties and particular external environmental features, especially with regard to the economic changes in property values in specific areas that had undergone a significant change in their neighborhood environment. Taking the property values of either residential properties or commercial properties as the dependent variable, most of these studies concluded that the property values could be changed either positively or negatively as a result of the addition of new appearance or tangible or intangible external environmental features such as airports, urban green areas, parks, changes of land use, noise levels, air quality, visible space, and green building certification.

The external environmental features that were examined in these previous studies shared one common feature: all were related to the quality of human life. Three studies selected a commercial property as the dependent variable and examined the correlation between property values and changes in external features in the surrounding environment. Two were directly relevant to the current study: Weinberger (2001) investigated the changes of commercial property values in a commercial area caused by the introduction of a light rail transit system near the commercial area, while Chun et al. (2011) looked at how changes in the visible space affect commercial property values in a commercial area. Both these studies demonstrated that how changing external environmental features could have a significant impact on the commercial property values of a specific area or a building and identified the direction of the resulting impacts. The findings of these previous studies were summarized in Table 4.1.

Table 4.1. Effects of external environmental features on neighborhood property values

	Response	Measurement	Effects
Nelson (1980)	Residential property values	Airport (Tangible)	Negative impact on property values due to the airport noise levels
Weinberger (2001)	Residential or Commercial property values	Light rail (Tangible)	Positive impact on property values and a rent benefit for the residential or commercial area due to the improved accessibility by a public transportation
Kim et al. (2003)	Residential property values	Air quality improvement (Intangible)	Positive impact on the willingness to pay by buyers due to a better quality of life
Mansfield et al. (2005)	Residential property values	Urban forests (Tangible)	Positive impact on the property value for residential property due to a better quality of life
Hui et al. (2007)	Residential property values	Sea view Green belt area Air quality Noise level Accessibility (Intangible)	Positive impact on the willingness to pay by buyers due to a better quality of life
Lin et al. (2009)	Residential property values	Foreclosure (Intangible)	Negative impact on property values of neighborhood area
Liu et al. (2010)	Commercial or Residential property values	Land use (Tangible)	Positive impact on the property values for both property areas, residential or commercial, due to a better quality of life
Chang and Chou (2010)	Neighborhood property values	A building's green design (Tangible)	Positive impact on the property values of neighborhood area due to the environmental improvement
Chun et al. (2011)	Commercial property values	Visible space (Intangible)	Positive impact on the property values due to a better quality of life
Saphores and Li (2012)	Residential property values	Urban green area (Tangible)	Positive impact on the property values due to a better quality of life
Suh et al. (2013)	Commercial property values	Green building certification; LEED (Tangible)	Positive impact on property values of neighborhood area

Of particular interest for this research, 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 or about 2,700 feet as the effective radius of properties suffering a significant negative impact. Chang and Chou (2010) reported that factors significantly associated with the project's greenness such as the building's green design had a positive impact on not only the building's reputation but also the entire local urban real estate market. Suh et al. (2013)'s findings supported those of Chang and Chou (2010), providing further evidence that green building certification, in this case LEED, had a positive impact on the property values of buildings adjacent to a LEED certified commercial building in that research.

The impact on local property values of a building with good walkability

Demographic factors such as the size of the local population, the range of ages, and the number of householders were a critical determinant of the supply and demand curve for a specific building, as are external features in the existing environment. A neighborhoodʹs socio-demographic factors have been shown to have a significant effect on individual property values, although these also depended on regional location factors and the physical characteristics of neighborhoods (Kim and Son 2011; Sohn et al. 2012). In particular, OʹSullivan (2009) listed the importance of demographics for office property rental values as follows:

- As the proximity to the central business district (CBD) increased, so does the rental rates due to the increased productivity of employees and reduced production expense.
- The higher density of population in a suburban sub-center area had a tremendous impact on the office rental rates.
- The office rental rates were determined by the opportunity to conduct face-to-face meetings, which depended on the number of employees of the service provider and the number of employees of the service recipient.

For these reasons, the proximity to the CBD is directly related to the demographic factors, and people who live in a metropolitan city generally prefer a walking distance to a biking or driving distance from their living space to their working place. Leinberger concluded that “People are clearly willing to pay more for homes that allow them to walk rather than drive. Biking is part of the picture, too. Biking and walking are part of a ‘complete streets’ strategy that public rights of way should be for all of society – not just cars” (2012, p. SR6). Therefore, the walkability of the walking distance has been the focus of several investigations into the effect of proximity between a subject building and a target building.

According to growing the interests of walking distance or walkability, “WalkScore” offered an online residential value evaluation service based on a complex algorithm that considers proximity to the types of amenities that residents considered essential in their neighborhood (Hinshaw 2012). The target area of this research, New York City (NYC), achieved the highest score in the country and was ranked the most walkable city in the United States in both 2011 and 2014 (WalkScore 2014). The score also indicated that the NYC public transportation systems were capable of assisting the city’s residents to commute to their work places and those residents in NYC were looking for homes or apartments in walkable areas; NYC Metropolitan Transportation Authority (NYCMTA) mentioned that any location on the island of Manhattan was within a 15 minute walk of a subway entrance (NYC MTA 2013). In addition, the needs of office and retail properties in the 30 largest U.S. metropolitan cities were correlated with their urban walkability, referred to as Walkable Urban Places (WalkUPs), based on the perceived walkability from a residential area to a workplace such as an office or retail outlet (Leinberger and Lynch 2014). 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 retailer workers should play a core role in the decision making for workplace locations in NYC. Walkability is also one of the most important external environmental factors affecting the decisions of workplace location made by employees commuting to work. NYC’s subway system is the busiest public transportation system in the U.S. and has the greatest ridership among all the transportation systems in NYC[14]. 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,

[14] MTA.info: Subway and Bus Ridership, http://web.mta.info/nyct/facts/ridership/

safe, and productive (Oklahoma City Embark 2013).

As mentioned above, it is possible to walk to a subway entrance within 15 minutes from anywhere in Manhattan, and this 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 various proximities that satisfy commuters for different types of final destinations, as shown in Table 4.2 below:

Table 4.2. Walkable distance considered convenient by pedestrians

Federal Highway Administration (FHWA) (2002)	0.25 miles (maximum distance considered to be a convenient distance)
Rood (2000); 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 theoretical 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 (Boyce 1984; Friedman et al. 2013). This definition also encompasses the actual cost when a buyer acquires the property ownership from a seller and the transaction is completed successfully (Boyce, 1984).

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 (Friedman et al. 2013), and Sohn et al. (2012) suggests a similar formulation, where the market value represents the sum of the buyer's willingness to pay and the buyer's and seller's satisfaction. In other words, the term "market value" could be considered as either the meaning of the transaction price or the actual sales price. New York City's Department of Finance (NYC's DOF) estimated the market value of individual property using three different approaches depending on the property's tax class. The calculation of market value is the starting point for estimating the taxable value of an individual property, and every property in the city has to submit an annual report that includes all the information needed to calculate their market value to NYC's DOF, who then estimates a market value based on the reported information for the fiscal year, which runs from July 1 through

June 30 of the following year.

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. Cypher and Hansz (2003) insisted that the flaws of assessed value with regard to indicating an actual market value or a real transaction price limited the validity of assessed value. Aydin et al. (2010) agreed, concluding that data on actual sales price should be preferred over the data used for tax appraisals because actual sales price data more accurately represents actual real estate market outcomes. Moreover, the Appraisal Institute (2002) presented two major reasons for there being only 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 related to property values 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 adopted by the Harris County Appraisal District (HCAD) in Texas and other similar agencies for all residential properties (Zhang 2010). 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 typical research period; and 2) the correlation between actual sales value and tax appraisals. Dermisi (2009) put forward three main reasons for using assessor-generated property values when studying LEED certified buildings, covering both total assessed values and market values: 1) the difficulty in obtaining actual transaction prices of properties; 2) recently constructed buildings have little or no transaction history; and 3) the general lack of awareness of the economic benefits to be gained from LEED certification and the consequences when comparing the results of current and future research using the same type of data, namely assessed property 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. Scanlon and Cohen concluded that “Whatever the particular technique, an income-based approach makes sense for income-producing commercial-residential property”[15]. Kim and Son (2011) 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) (2011) 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. 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 only considered the information on LEED and Energy Star certifications, and it utilized one estimated value, market value, when calculating the property tax for individual properties. The market value is the primary property value for tax calculation, and it is also a fundamental input for calculating the assessed value. The DOF does not impose any caps for increasing price or decreasing price, just as actual sales prices or real transaction prices does not. In addition, NYC’s DOF provides two different types of tax reduction: exemption and abatement, both of which are directly connected to not only the assessed value but also the taxes assessed because the assessed value is reduced by an exemption before calculating a tax while the tax itself is reduced by abatement, thus sidestepping the second of the two issues raised by the Appraisal

[15] http://www.manhattan-institute.org/email/crd_newsletter04-09.html

Institute (2002). Overall, the market value estimated by the DOF seems to represent the property value reasonably well for all properties in NYC because they continually strive to reduce the gap between their estimated market value and actual sales prices or transaction prices.

Establishing the property values in the neighborhood of LEED and/or Energy Star certified office building utilizing the Hedonic Price Equation and Linear Mixed Effect Model

Theoretically, the hedonic price model is useful to measure the value of the environment using cross-sectional data for land values (Kanemoto 1997; Reichert 2002; Lee 2010). In addition, both 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 characteristics of both the socio-economic and physical make-up of a neighborhood. The hedonic price model was also widely applied to evaluate the valuation of residential property, especially in mass appraisals in the U.S. (Dunse and Jones 1998). Kim and Son (2011) agreed, pointing out that the hedonic price model was a useful model for analyzing real estate markets, which were inherently heterogeneous. 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 in the real estate market in both the United Kingdom (U.K.) and the U.S. (Hough and Kratz 1983; Fisher et al. 1994; Dunse and Jones 1998; Weinberger 2001; Chun et al. 2011).

To arrive at a better determinant coefficient (R^2), the hedonic price model provides four different model equations for transforming the data sets in order to identify the most appropriate hedonic price model. Depending on the type of transformations acting on a response variable and its explanatory variables, one of the four different model equations can be selected on the closest linear equation graph. The four different model equations that can be applied to hedonic price model equations are as follows:

- Linear function $p_i = a_0 + a_1z_1 + \cdots\cdots + a_nz_n + \varepsilon_i$

- Log-linear function $p_i = a_0 + a_1\log(z_1) + \cdots\cdots + a_n\log(z_n) + \varepsilon_i$

- Semi-log function $\log(p_i) = a_0 + a_1z_1 + a_2z_2 + \cdots\cdots + a_nz_n + \varepsilon_i$

- Log-log function $\log(p_i) = a_0 + a_1\log(z_1) + \cdots\cdots + a_n\log(z_n) + \varepsilon_i$

Note. p_i: a value of response variable, a_p: coefficient, z_p: explanatory variables, ε_i: an error term, where i = {1,…, n} and n is the number of subjects in the data.

There was, however, a limitation on applying the hedonic price model for the current study as it lacked the capacity to analyze the impact of a LEED or/and Energy Star certified office building on its neighborhood areas over time. The hedonic price model focuses on a certain point in time when analyzing the effect of external environmental features on property values of buildings in the neighborhood areas, but this research was interested in the effect over an eight year period. The linear mixed effect model offers a more useful way to investigate changes in the market value of neighborhood properties over time. This approach considers both fixed effects and random effects. The fixed effects of the explanatory variables for the response are examined for all possible category values and the random effects vary as the subjects or the groups appear when only a random sample of possible category values is measured. In particular, a linear mixed effect model is helpful when analyzing repeated measure data or cross-sectional data in various research disciplines (Song 1999; Starkweather 2010; Kang and Kim 2011; Seltman 2014). 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 (SPSS 2005). Additionally, researchers can 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 (Song 1999; Seltman 2014). The fundamental equation of linear mixed effect model is as follows:

$$y_{ij} = \beta_1 x_{1ij} + \beta_2 x_{2ij} \ldots \beta_n x_{nij} + b_{i1} z_{1ij} + b_{i2} z_{2ij} \ldots b_{in} z_{nij} + \varepsilon_{ij}$$

Note. β_n: Fixed effect coefficients, x_{nij}: Fixed effect variables for observation j in group I, b_{in}: Random effect coefficients, z_{nij}: Random effect variables, ε_{ij}: the error for case j in group i

Problem statement

The impacts of LEED or Energy Star certification have been examined by numerous researchers through various economic measurements, and most have found that the certifications had a positive impact on the property values of the certified buildings (McGraw-Hill Construction 2008; Miller et al. 2008; Eichholtz et al. 2010; Wiley et al. 2010; Fuerst and McAllister 2011). Other researchers have focused on the impact of external features in existing environments on neighborhood property values (Nelson 1980; Weinberger 2001; Kim et al. 2003; Mansfield et al. 2005; Hui et al. 2007; Lin et al. 2009; Liu et al. 2010; Chang and Chou 2010; Chun et al. 2011; Saphores and Li 2012; Suh et al. 2013). Several studies have also investigated the impact on neighborhood areas of improvements to private spaces or conceptual aspects such as a building's green design and visible space and green building certification (Chang and Chou 2010; Suh et al 2013).

A thorough review of the relevant literature identified a research question that has not yet been addressed concerning the possibility of different impacts of LEED and/or Energy Star certified office buildings on neighborhood property values, possibly depending on the physical distance 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, which then affects buildings in the neighborhood in the same way as a characteristic like a foreclosure because certifications have an effect, in this case a positive one, on the property value of the certified buildings. Thus, LEED or Energy Star certification could be also expected to exert various strengths of impacts on median unit market values of other buildings in the neighborhood.

In line with this reasoning, 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 other buildings in their neighborhoods from an economic standpoint for both the local real estate market and the community as a whole. This study was designed to measure the impact of a LEED and/or Energy Star certified office building on the median unit market value of other buildings in its surrounding neighborhood based on the concept of walkable distance in terms of the change of unit market value of the LEED and/or Energy Star certified office building, the achievement of LEED and/or Energy Star certification, and the two major characteristics of LEED certification: LEED certification coverage and LEED certification level. A spatial analysis approaches utilizing ArcGIS 10.1 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. Two statistical analysis models, the hedonic price model and the linear mixed effect model, were also utilized to identify any correlations between the independent variables and the dependent variable. The output of this research is expressed numerically to represent the strength and direction of the impact of the independent variables on the dependent variable from an economic standpoint.

Methodology

Study area

NYC is one of the most active metropolitan areas for green buildings, including the achievement of green building certification, in the U.S. This emphasis was supported by initiatives such as PlanNYC, which recently published a guide to providing better public services in order to maintain the high quality of residents' lives through meeting their needs, enhancing their economic status, and solving the environmental problems arising from climate change (The City of New York 2014). NYC has the second largest number of LEED certified buildings in the U.S. and also has one of the highest numbers of buildings that have achieved Energy Star certification, with the 4th largest number of Energy Star certified building in 2012 among U.S. metropolitan cities. Interestingly, approximately 80 percent of LEED certified buildings in NYC are located in Manhattan, and Energy Star certified buildings present a similar trend in this metropolitan city. At present, almost 90 percent of the office buildings having LEED certification, Energy Star certification, or both in NYC are located on the island of Manhattan. Warren et al. (2013)

also singled out NYC and Washington D.C. as markets with good or better investment prospects in 2011, and NYC was the only U.S. metropolitan city which has been consistently selected as a good or better investment prospect in the real estate market since 2011 (Warren et al. 2013). Therefore, this research focused on Manhattan, one of NYC's five boroughs (the others being the Bronx, Brooklyn, Queens, and Staten Island).

Data sources and variables

The geographic information for LEED and/or Energy Star certified office buildings was available from various organizations such as CoStar Group, Honest Building Inc., USGBC, and the EPA, but the information provided by each of these organizations for LEED or Energy Star certified office buildings differs slightly. It was necessary to maintain accurate and consistent data for research projects due to the slightly different information available for selected buildings, 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 was provided by NYC's Department of City Planning (DCP) database.

The data on Geographic Information System (GIS) is also provided by NYC's DCP, whose GIS data set is updated regularly. The most recent update of the GIS data set, used here, was in October 2013. The GIS data files supported ArcGIS 10.1.

The market value data set is provided by NYC's Department of Finance (DOF), and was available to download from their website for the fiscal years (FY) 2009 through 2015; data not provided on their website were accessed by a Freedom of Information Law (FOIL) request for the market value data from FY 2007 and FY 2008 from NYC's DOF, which provided the electronic data files. Market values for the selected LEED and/or Energy Star certified buildings and buildings in their neighborhoods from 2007 through 2013 were as listed in NYC's DOF database. All market values were based on the FY for annual financial reports for all properties in NYC, which ran from July 1 through June 30 the next year.

Various data measurement periods were covered with each data set. The data sets provided by USGBC and EPA were from 2007 through 2013 and from 2003 through 2013 for this research, respectively. Based on the available data, the market value data for LEED and/or Energy Star certified building and their neighborhood areas were selected for the period from FY 2007 through FY 2013.

The measurements of data for the variables considered in this research are described in Table 4.3. 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, such as the LEED certification level and coverage, Energy Star certification renewal, building area, number of floors, building age, etc., as independent variables in both the hedonic price model and linear mixed effect model. In particular, this research took the median unit market values of buildings in the surrounding neighborhood rather than the mean value as the dependent variable to avoid the limitations of the mean value theorem. The mean value might not be an appropriate representative property value for a specific area because a large number of high or low outliers could generate a skewed distribution of unit market values (Smith and Huang 1995). The median value, on the other hand, is widely taken to be a good measure of the market value of properties in a certain area and a better indication of market trends, consumer sentiment and market conditions (Cossar 2013).

Table 4.3. 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 LEED certification:1/Full LEED certification: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 dollars) 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, where using the mean value may be risky due to big or small outliers.	NYC's DOF

Defining the coverage and level of LEED certification for a LEED certified office building achieving multiple LEED certifications

The performance of a building that has achieved Energy Star certification must be re-evaluated annually in order to renew its Energy Star certification. Energy Star certification is also a relatively simple binary measure: either the building achieves the certification or it doesn't – there are no specific classifications for Energy Star certified buildings. It is not necessary to re-evaluate the building performance of a LEED certified building when renewing LEED certification for the next year, however, and LEED certification consists of two major characteristics, the coverage and level, both of which specifically indicate differences in LEED certification between LEED certified buildings. Moreover, LEED certification allows the achievement of a further 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. Table 4. 4 presents the number of LEED certified office buildings that achieved multiple LEED certifications included in this study.

Table 4.4. The number of LEED certified office buildings achieving multiple LEED certifications

No. of LEED certifications	Two LEED certifications	Three LEED certifications	Four LEED certifications
No. of LEED certified office buildings	13	1	1

This study re-defined the coverage and level of LEED certified office buildings when they achieved additional 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 LEED certification coverage, and the higher level of LEED certification, which ranges from Certified, the lowest, through Platinum, the highest, was given priority when defining the level of LEED certification awarded to an office building. For instance, a LEED certified office building that had achieved one LEED certification for the whole office building with a Gold level as its first LEED certification, and then achieved additional LEED certifications for parts of the office building with two Platinum levels was treated as having Gold LEED certification for the whole building for the purposes of this study. Table 4.5 lists the results of defining the coverage and level of 15 LEED certified office buildings in this study.

Table 4.5. Information on the coverage and level for LEED certified office buildings and the definition of the coverage and level of LEED certified office buildings

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

This research sought to identify the correlation, if any, between the attributes of a LEED and/or Energy Star certified office building and the median unit market value of buildings in the surrounding neighborhood. In general, 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 (Appraisal Institute 2002; Friedman et al. 2013). This definition has been adapted for this research by considering several conditions of the research question. As mentioned earlier, walkable distance is a core external environmental feature that is widely used to estimate the market value of a certain building because the walkable distance directly relates to public transportation ridership and other demographics that contribute directly to fostering more livable neighborhoods from the economic, safety, and productivity standpoints. 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, as in previous studies (Rood 2000; FHWA 2002; Dill 2003; Sohn et al. 2012). 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. It was necessary to understand the geographic information related to the LEED and/or Energy Star certified office buildings and their neighborhood areas to integrate all the available geographical, physical and economic information for individual buildings, collected from various data sources using ArcGIS 10.1. A statistical approach was then applied to analyze the correlation between the independent variables and the dependent variable and to indicate the direction of the correlation numerically. These are explained in more detail below.

- Geographical method 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. The detailed tasks involved in this process were as follows:

  - Create a map containing all the information for the LEED and/or Energy Star certified office buildings in Manhattan, along with other relevant features of the certified buildings as the independent variable.

- Pinpoint and designate the surrounding neighborhood area of each LEED and/or Energy Star certified office building within a 0.25-mile-radius, chosen based on the walkable distance, on the map created in the previous step.
- Distinguish the individual buildings included in each neighborhood surrounding a certified building from all buildings located in Manhattan NYC.
- Construct an overall data sheet that includes all the primary information to be applied to the statistical analysis using a statistical computing tool, after which the overall data sheet can be integrated by matching the number of each Borough-Block-Lot (BBL) from the raw data.
- Export the integrated secondary data using a CSV file, whose format is accepted by "R-Project 3.0.2" to obtain the regression results of this research.

• Statistical methods applied

Statistical methods were applied to obtain the numerical results with which to interpret the correlation between the independent variables and the dependent variable using "R-Project 3.0.2" based on two regression models, the hedonic price model and the linear mixed effect model. This study examined the impact of LEED and/or Energy Star certified office buildings on the median unit market value of buildings in their surrounding neighborhood; as shown above in Table 4.3, the independent variables in this research consisted of major features of the LEED and/or Energy Star certified office buildings such as their unit market values and the specific characteristics of their LEED and Energy Star certifications. The screened population of LEED and/or Energy Star certified office buildings included in the study consisted of the office buildings that achieved LEED and/or Energy Star certification at least once within the research period (2007 through 2013) in Manhattan, NYC. Hence, 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. The relationship between the unit market value of a LEED and/or Energy Star certified office building and the median unit market value of buildings in the neighborhood was deemed an appropriate way to represent the impact of the LEED and/or Energy Star certification of each building on its neighborhood area over time because the unit market value of the LEED and/or Energy Star certified office buildings should already reflect the change of the status of LEED and/or Energy Star certification on the certified building itself. In general, the unit market value of a LEED and/or Energy Star certified office building was taken to include all unit market values of that building for every year throughout the study period, even if the value had risen or fallen since the LEED and/or Energy Star certification were achieved by that building. Furthermore, the independent variables consisted of not only the unit market value of the LEED and/or Energy Star certified office buildings themselves but also the major features of their LEED and/or Energy Star certification in order to identify any correlations between the certifications and the unit market value of buildings in their neighborhoods. Therefore, the results of statistical methods should indicate the correlation between the unit market value of each LEED and/or Energy Star certified office building and the median unit market value of buildings in its neighborhood. Specific tasks were involved as follows:

- Select two different analyses that meet the needs of this research: descriptive analysis and regression analysis.

- Analyze the secondary data based on the hedonic price model and the linear mixed effect model.

- Identify the correlations between the independent variables and the dependent variable to comprehend the impact of LEED and/or Energy Star certification statistically from a socio-economic perspective.

- Identify all the coefficients needed to complete the equation for the linear mixed effect model, which is based on the hedonic price model, and determine the direction of the impact of LEED and/or Energy Star certification from the coefficient values.

- Validate the numerical models based on the statistical results using the Log-likelihood ratio statistics, which could explain the fitness of numerical models of this study through the comparison between the fitted model and the null model.

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. The distribution of LEED and/or Energy Star certified office buildings and buildings in their neighborhood is shown in Figure 4.3 through Figure 4.20 using the ArcGIS 10.1 tool with a basic parcel map which was provided by NYC's DCP.

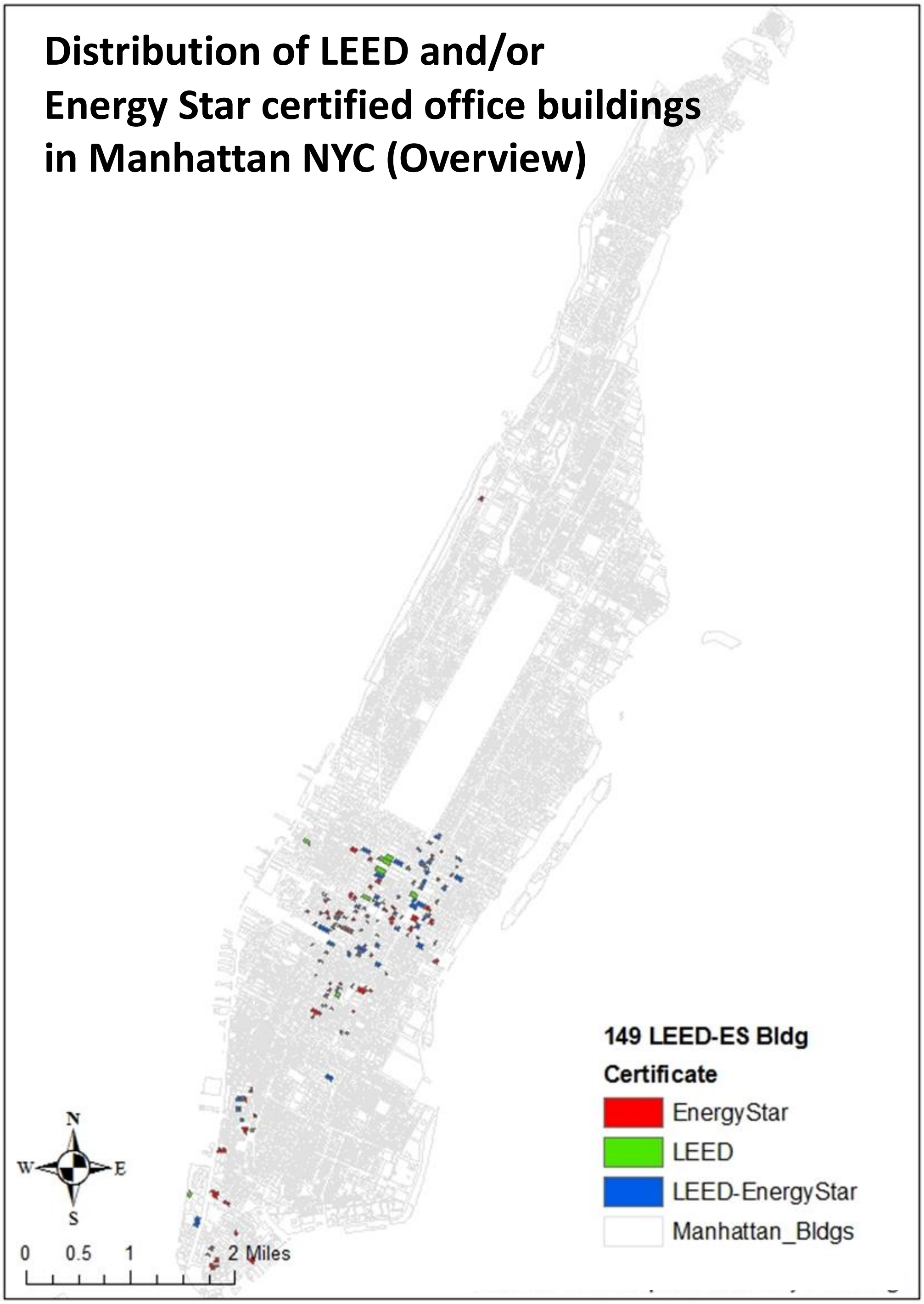

Figure 4.3. Distribution of LEED and/or Energy Star certified office building in Manhattan NYC (Overview)

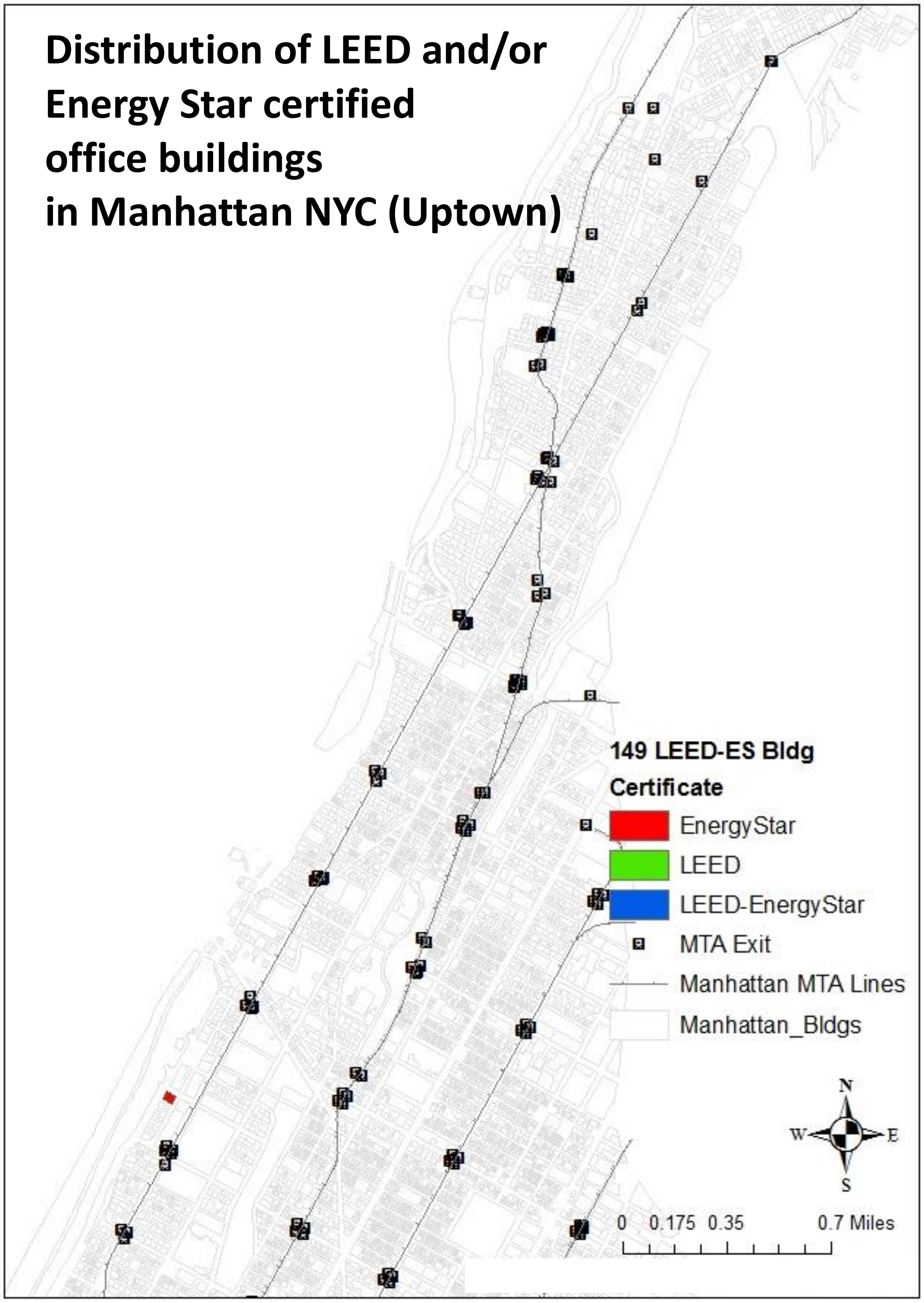

Figure 4.4. Distribution of LEED and/or Energy Star certified office building in Manhattan NYC (Uptown)

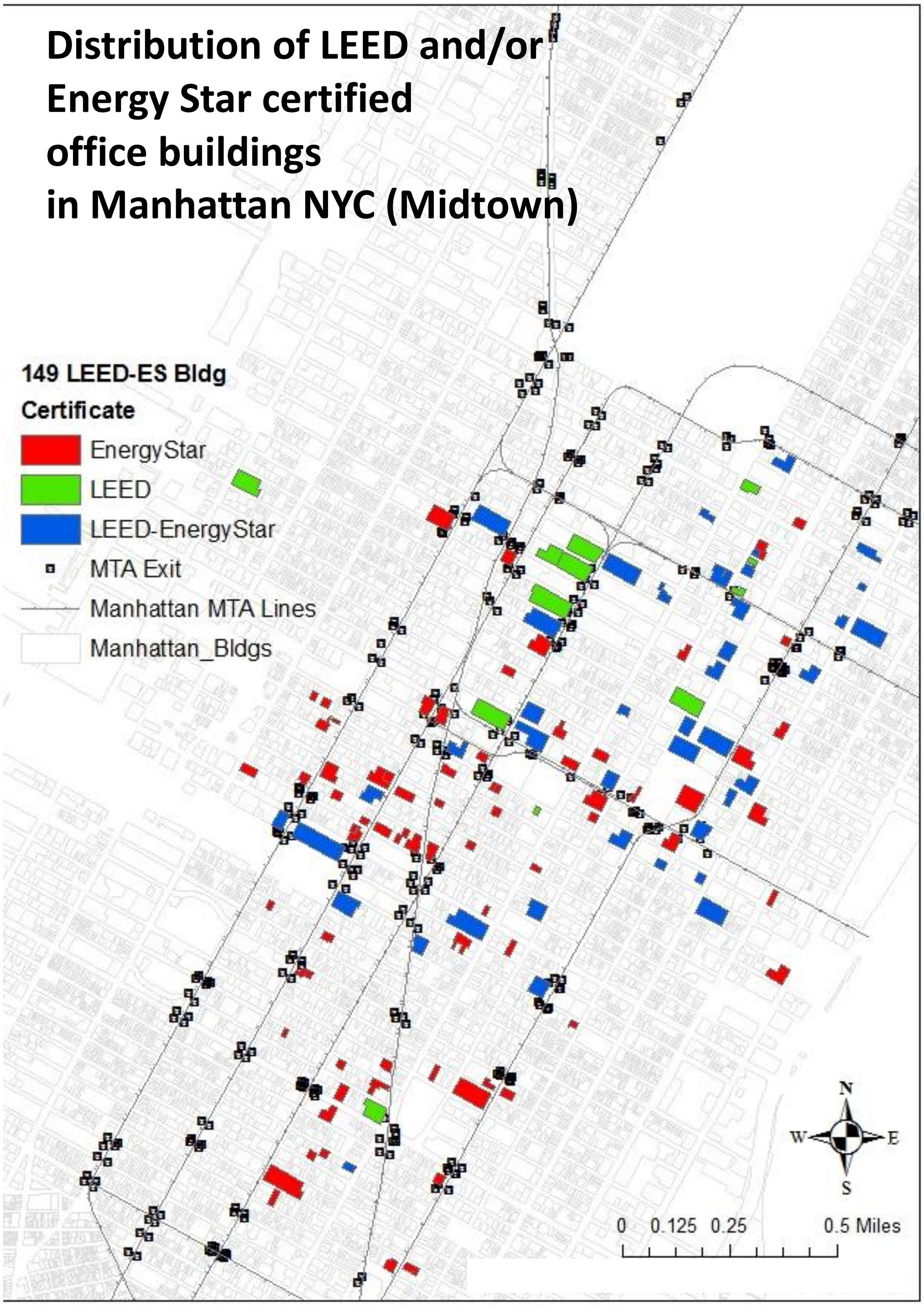

Figure 4.5. Distribution of LEED and/or Energy Star certified office building in Manhattan NYC (Midtown)

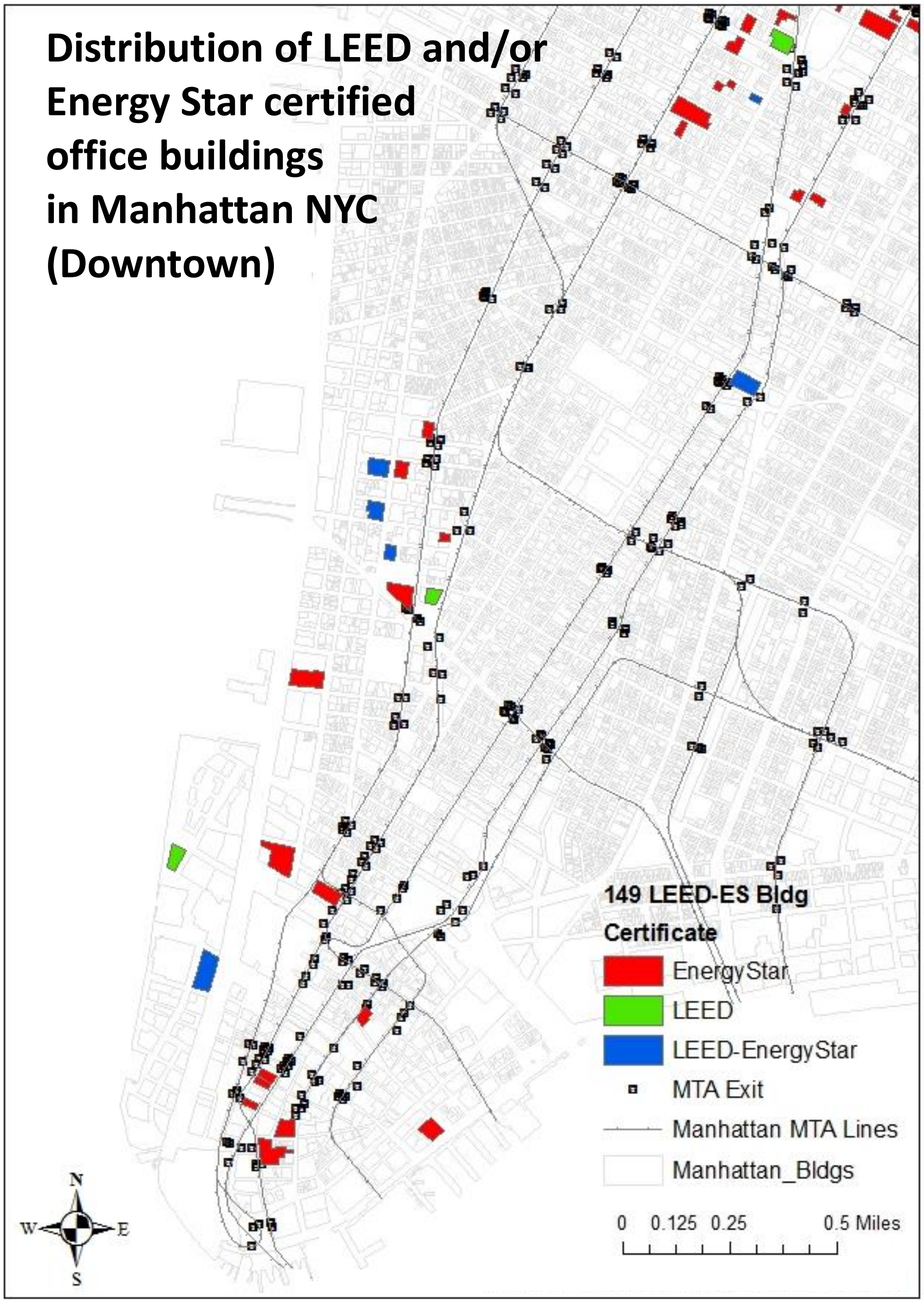

Figure 4.6. Distribution of LEED and/or Energy Star certified office building in Manhattan NYC (Downtown)

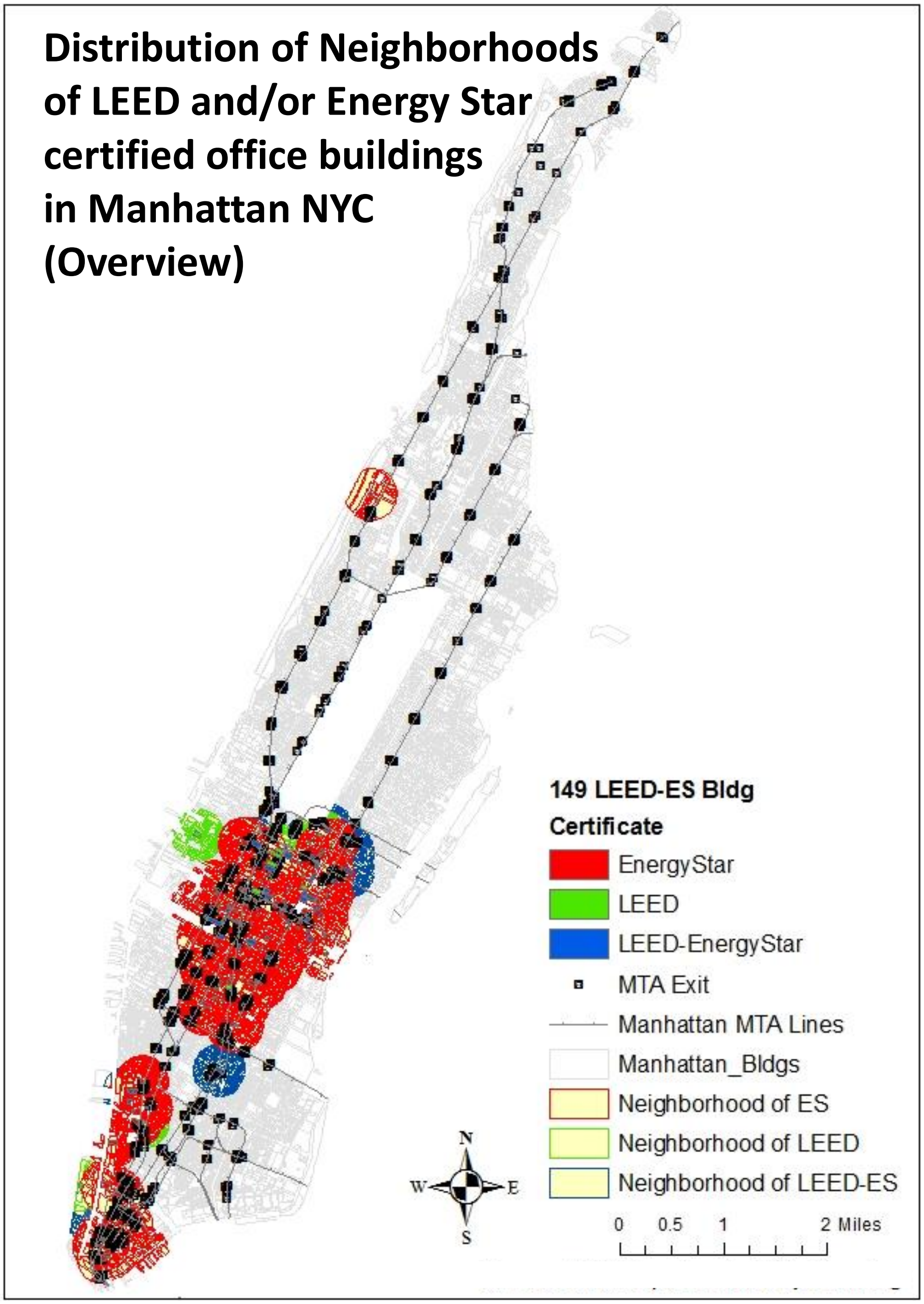

Figure 4.7. Distribution of neighborhood of LEED and/or Energy Star certified office building in Manhattan NYC (Overview)

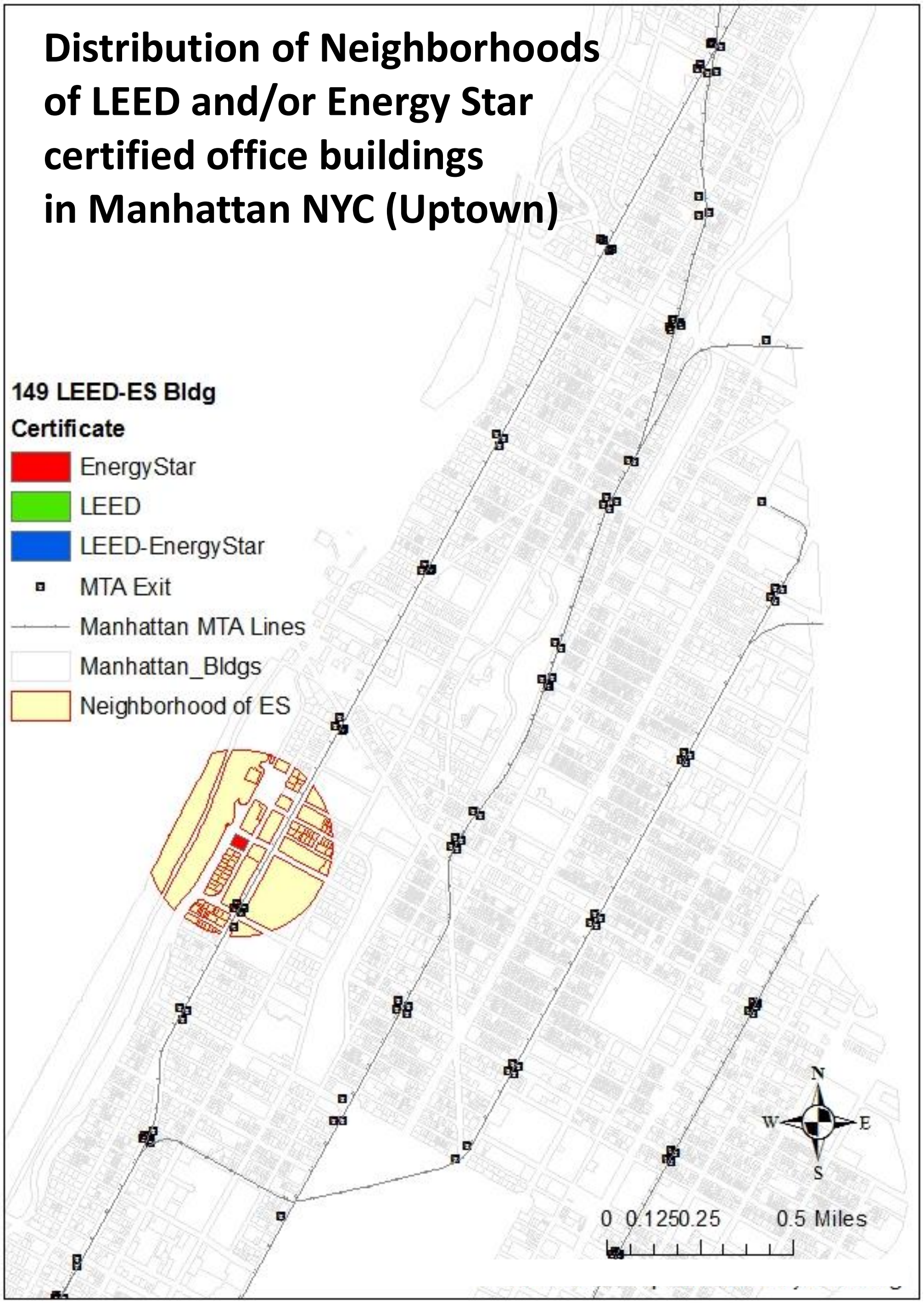

Figure 4.8. Distribution of neighborhood of LEED and/or Energy Star certified office building in Manhattan NYC (Uptown)

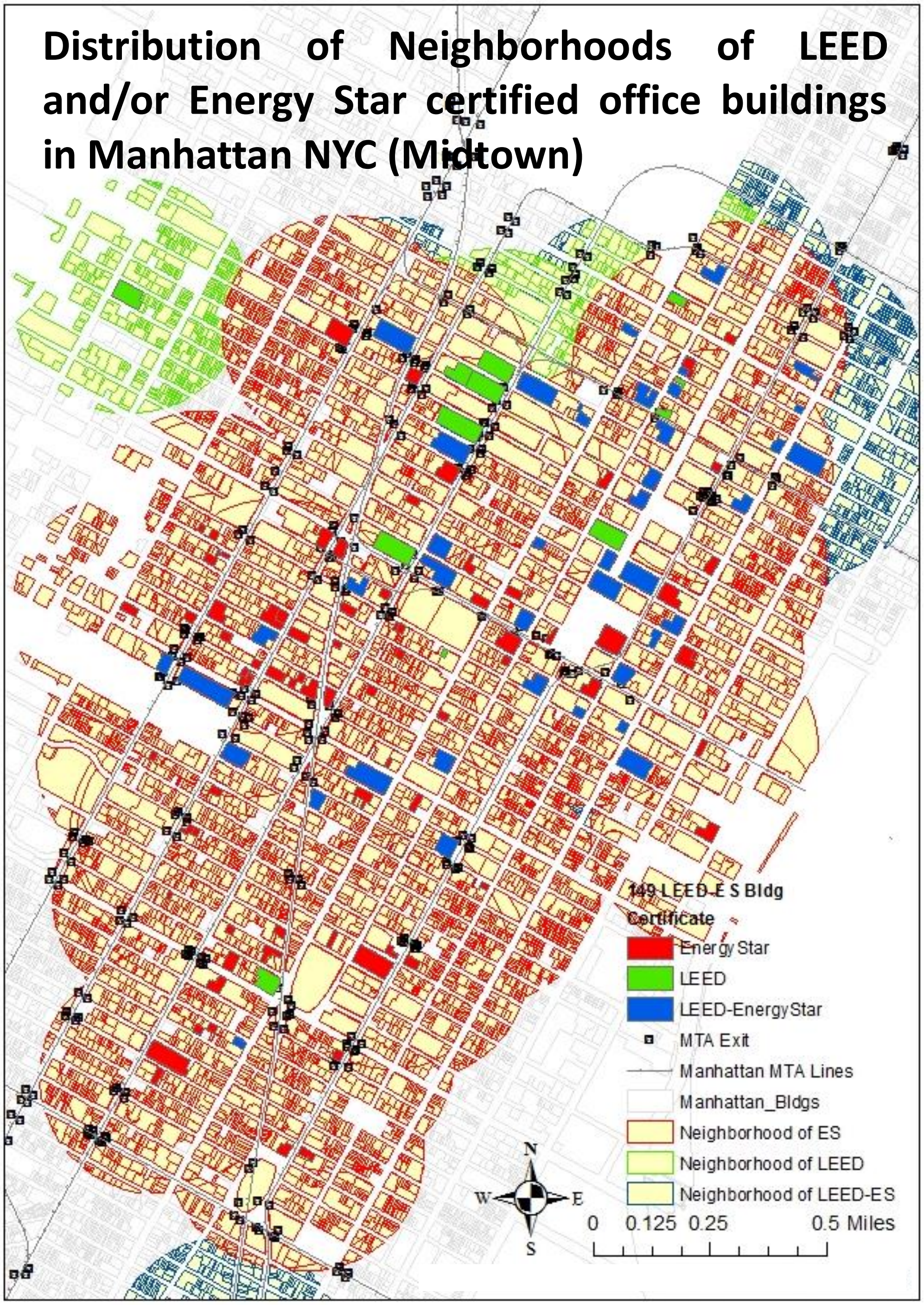

Figure 4.9. Distribution of neighborhood of LEED and/or Energy Star certified office building in Manhattan NYC (Midtown)

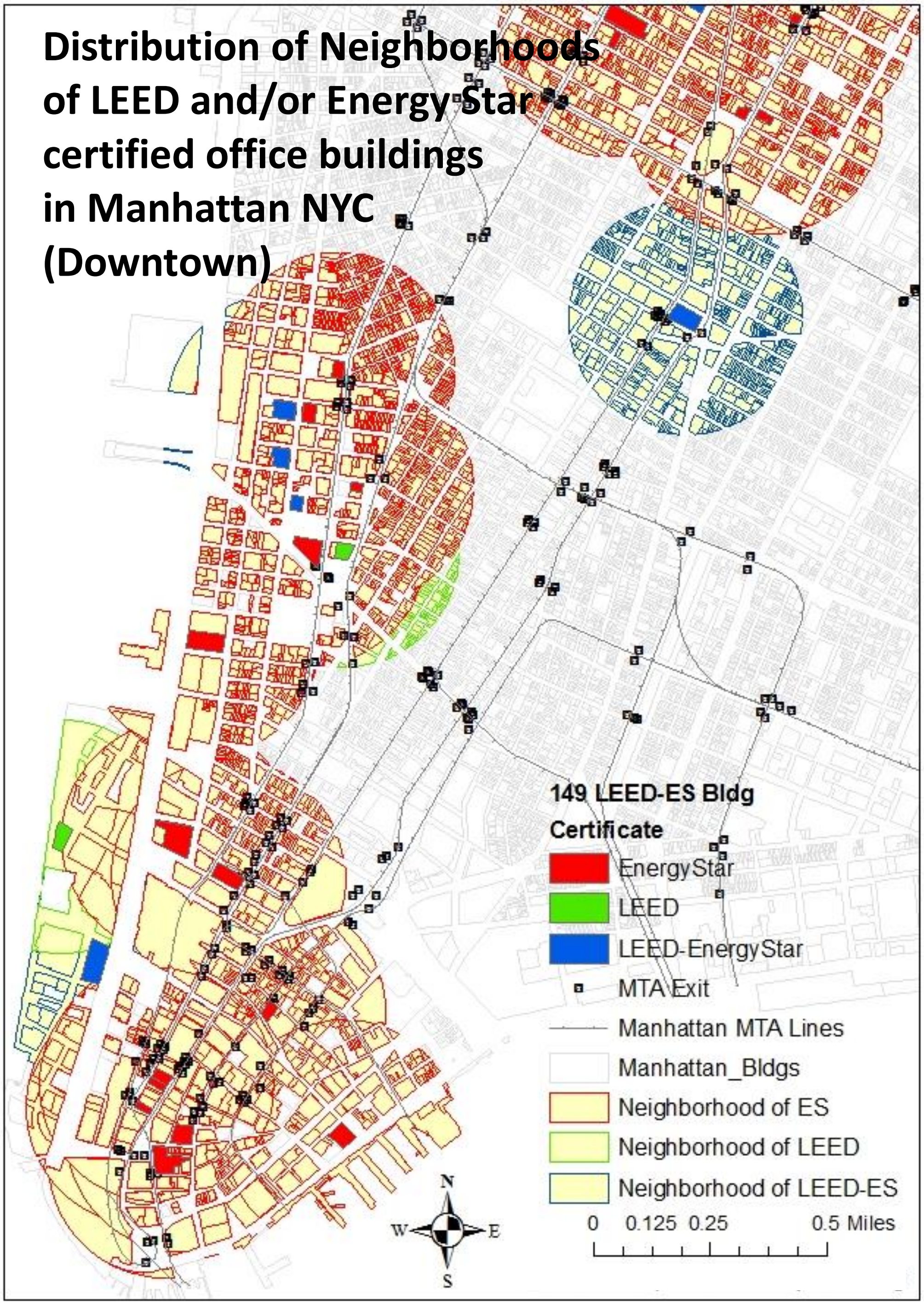

Figure 4.10. Distribution of neighborhood of LEED and/or Energy Star certified office building in Manhattan NYC (Downtown)

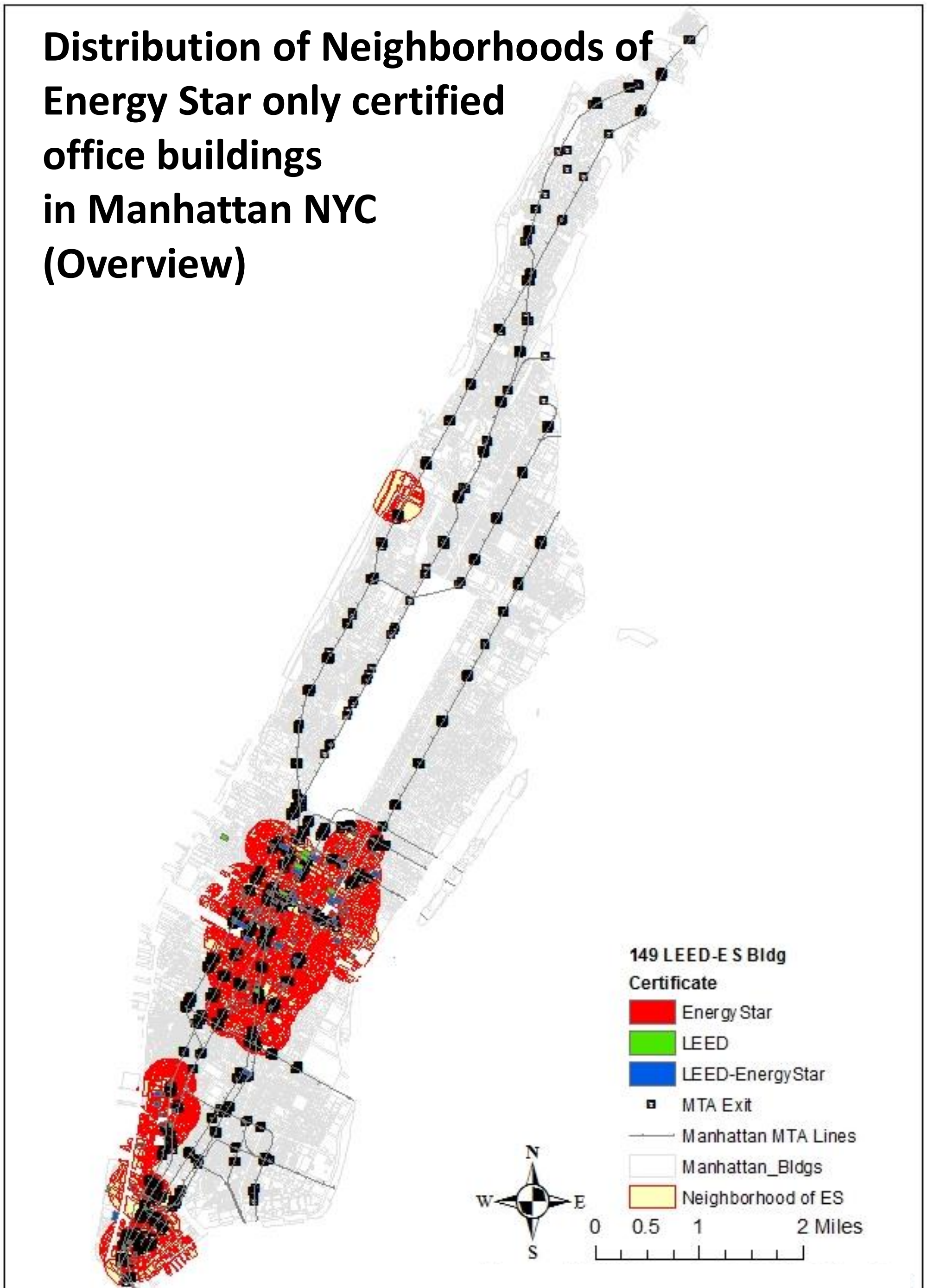

Figure 4.11. Distribution of neighborhood of Energy Star only certified office building in Manhattan NYC (Overview)

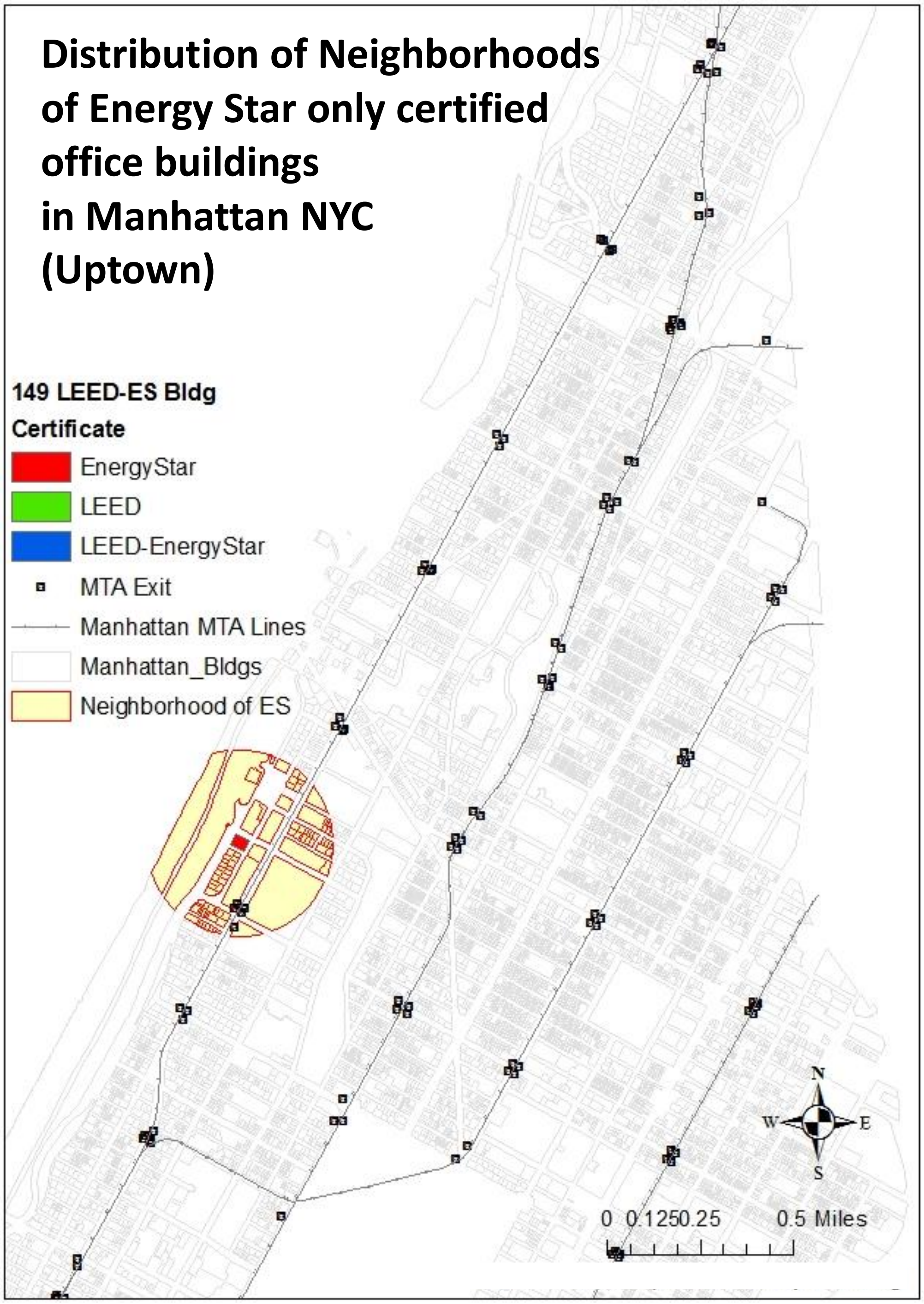

Figure 4.12. Distribution of neighborhood of Energy Star only certified office building in Manhattan NYC (Uptown)

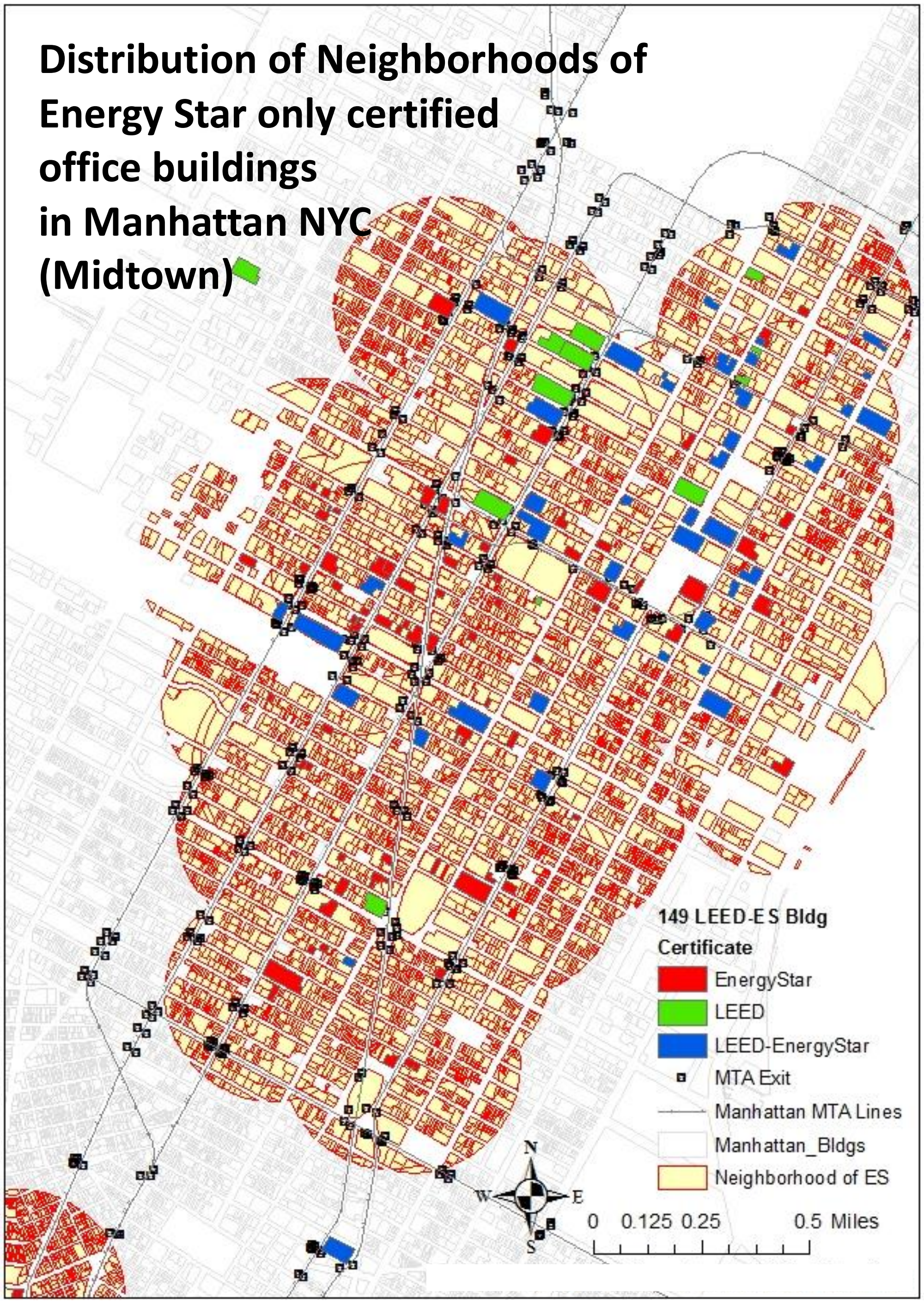

Figure 4.13. Distribution of neighborhood of Energy Star only certified office building in Manhattan NYC (Midtown)

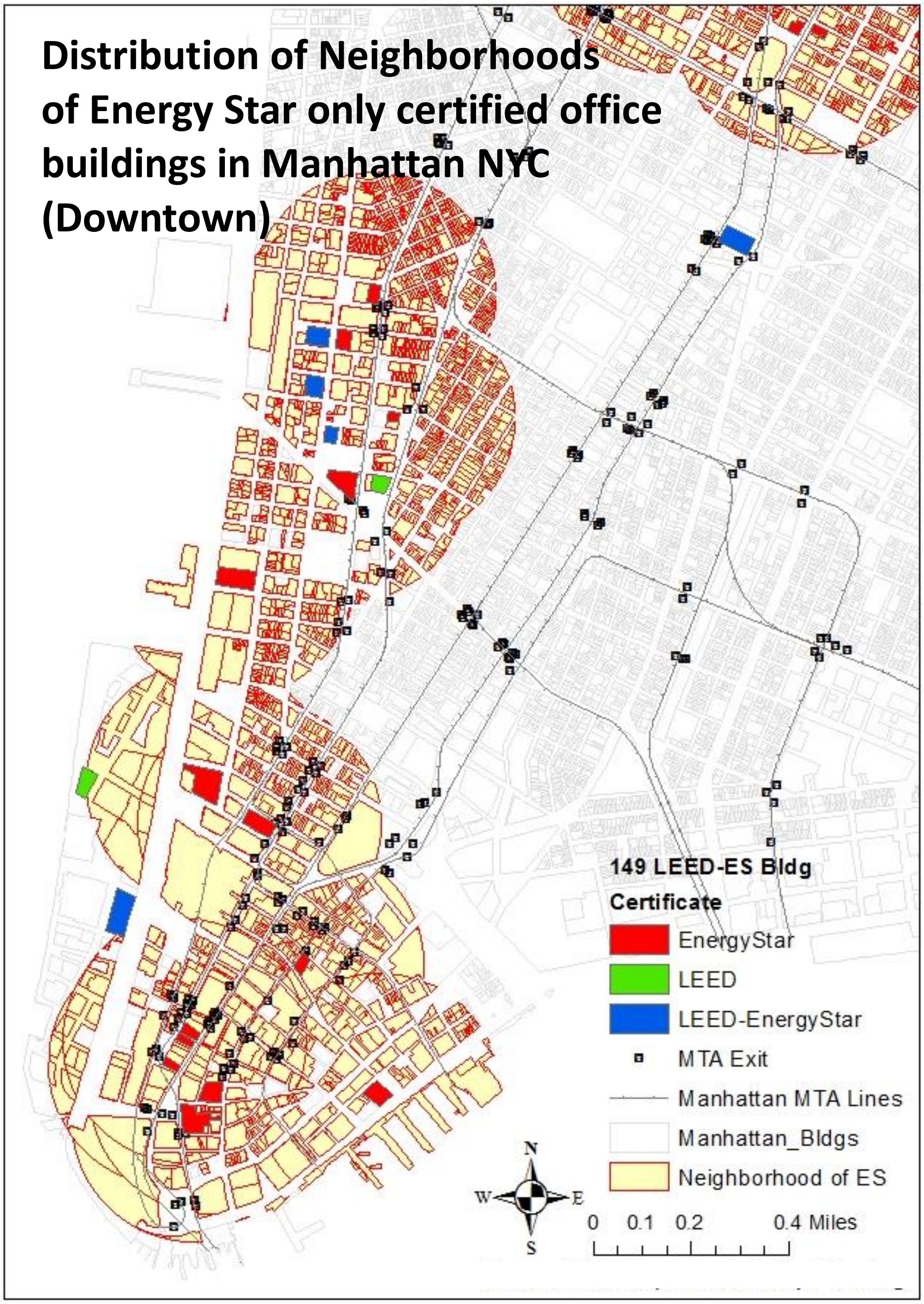

Figure 4.14. Distribution of neighborhood of Energy Star only certified office building in Manhattan NYC (Downtown)

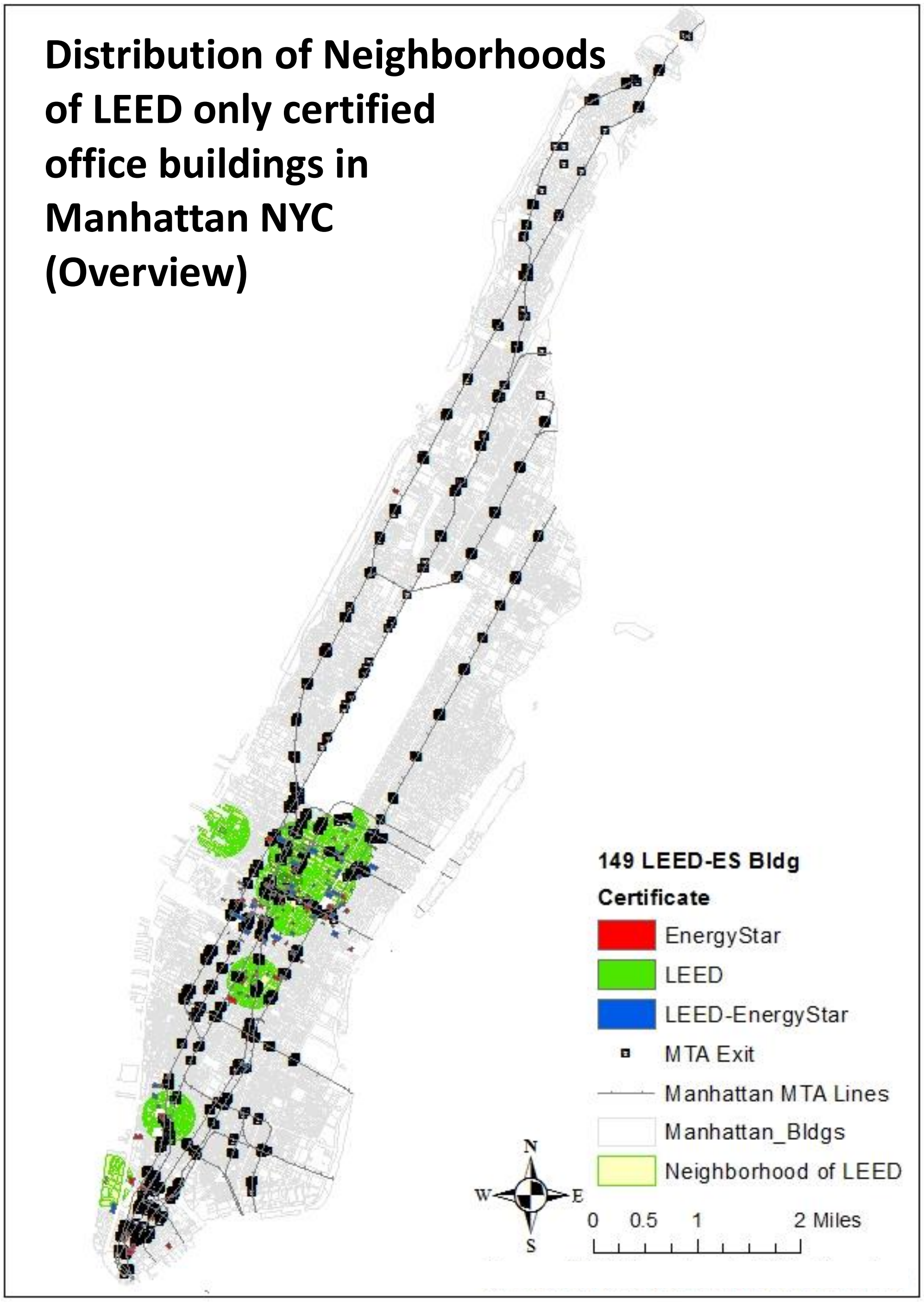

Figure 4.15. Distribution of neighborhood of LEED only certified office building in Manhattan NYC (Overview)

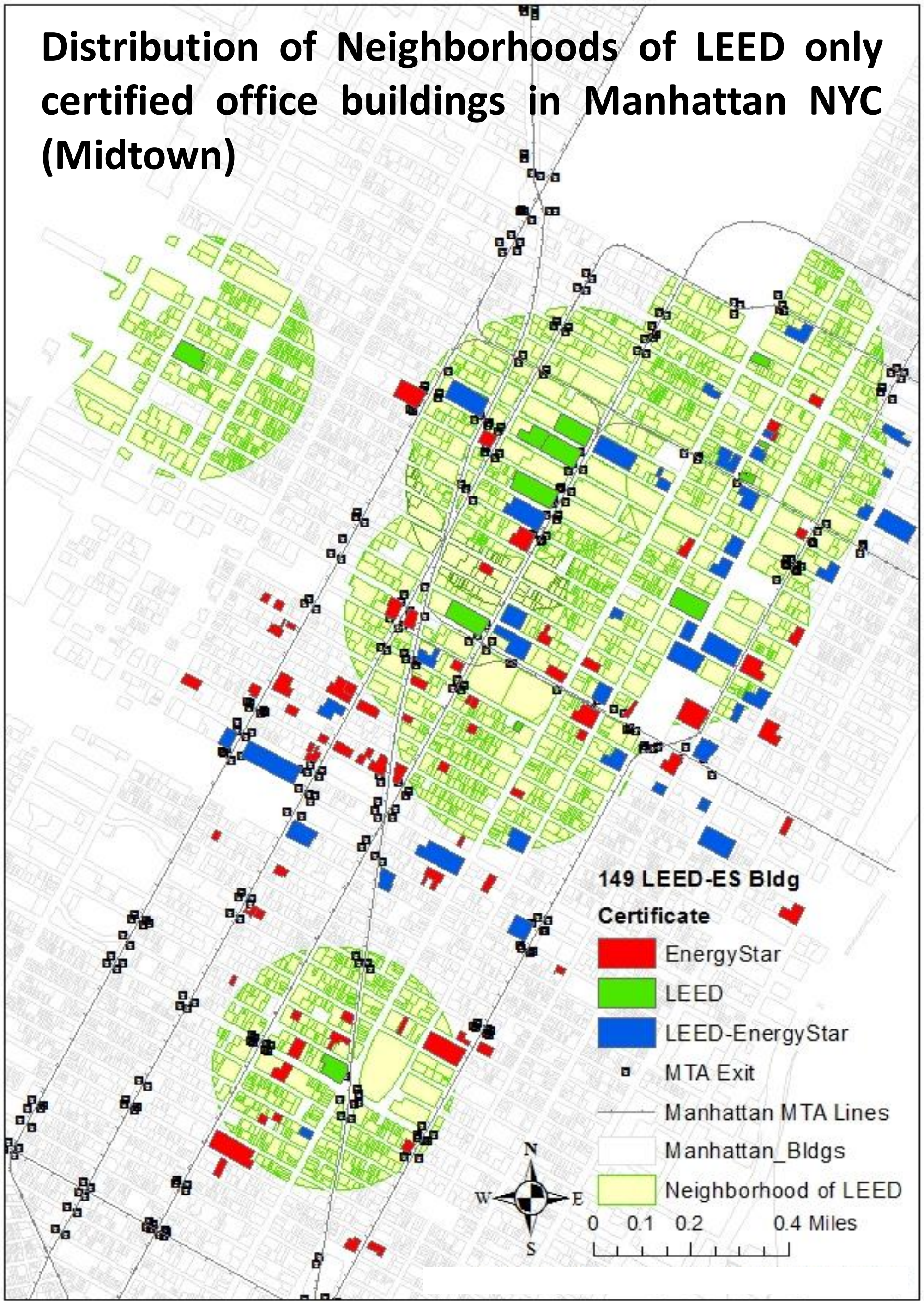

Figure 4.16. Distribution of neighborhood of LEED only certified office building in Manhattan NYC (Midtown)

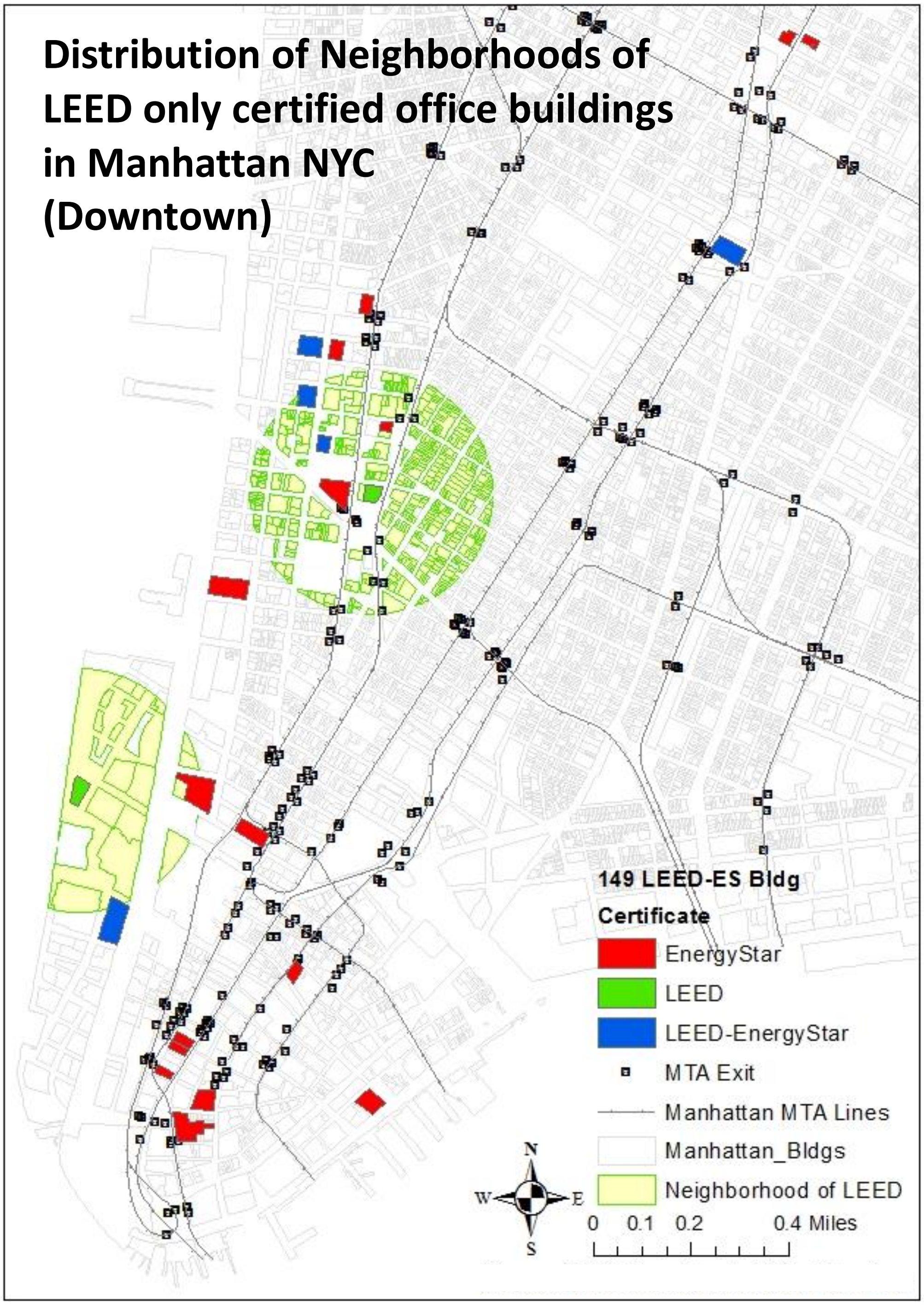

Figure 4.17. Distribution of neighborhood of LEED only certified office building in Manhattan NYC (Downtown)

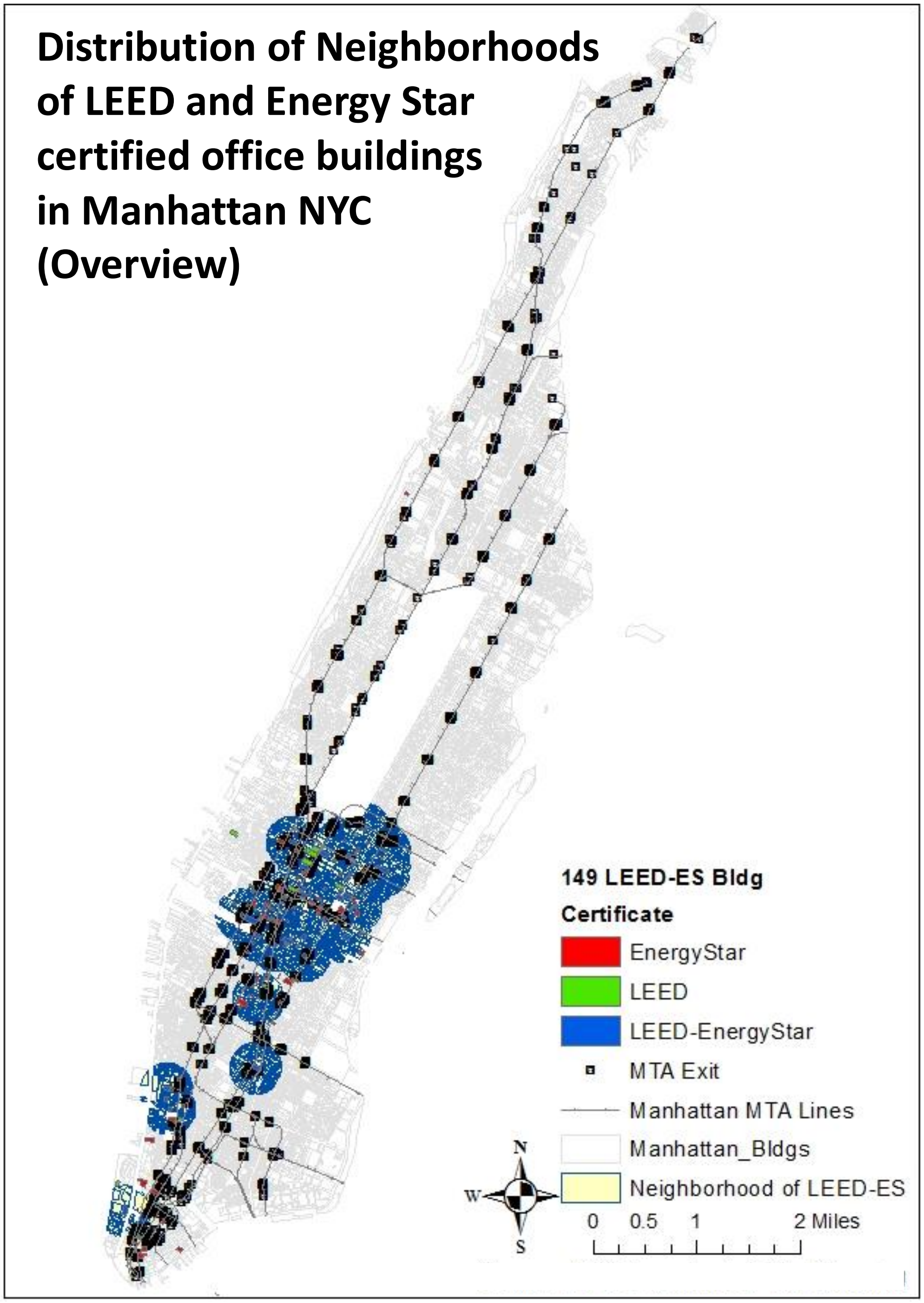

Figure 4.18. Distribution of neighborhood of LEED and Energy Star certified office building in Manhattan NYC (Overview)

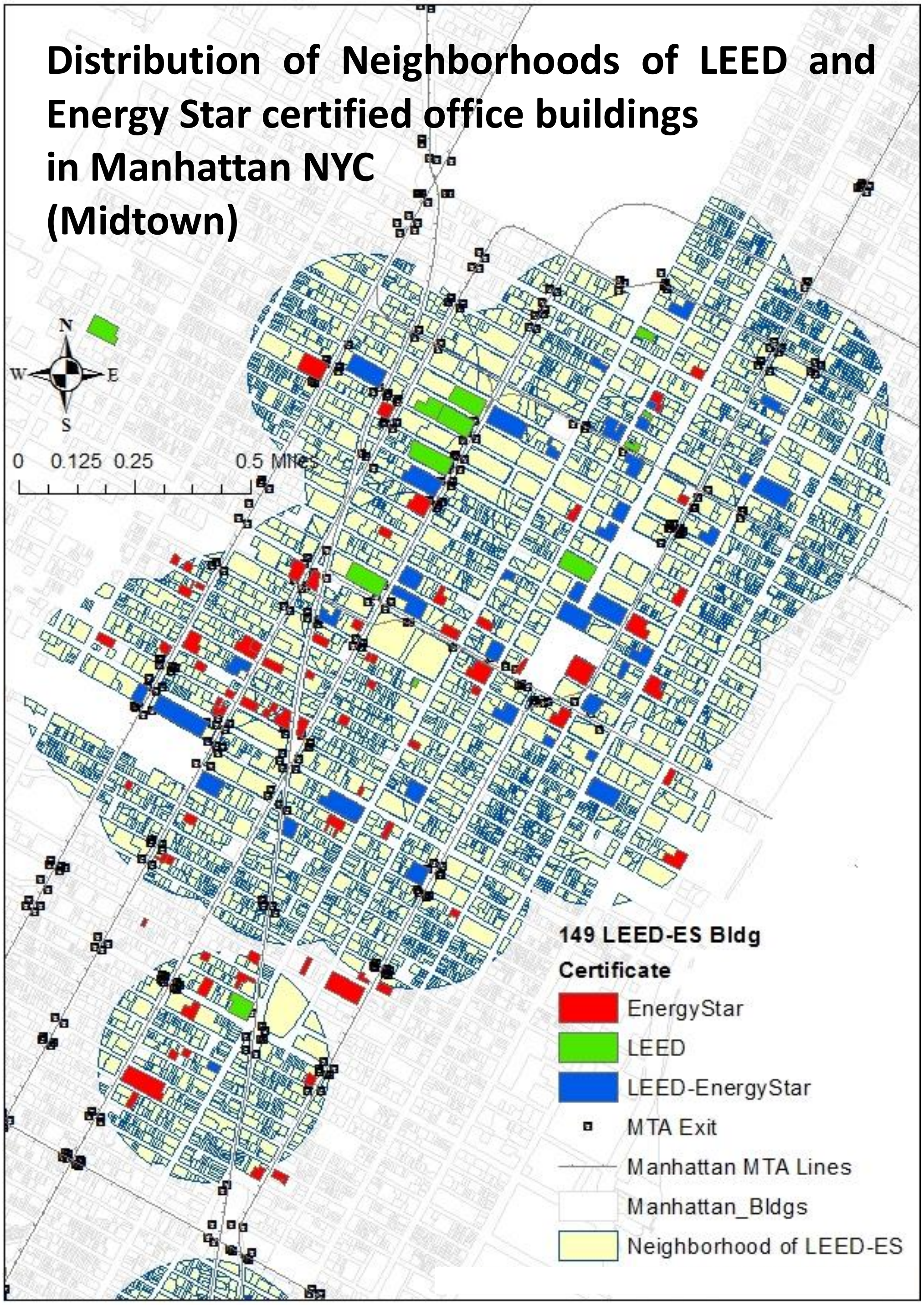

Figure 4.19. Distribution of neighborhood of LEED and Energy Star certified office building in Manhattan NYC (Midtown)

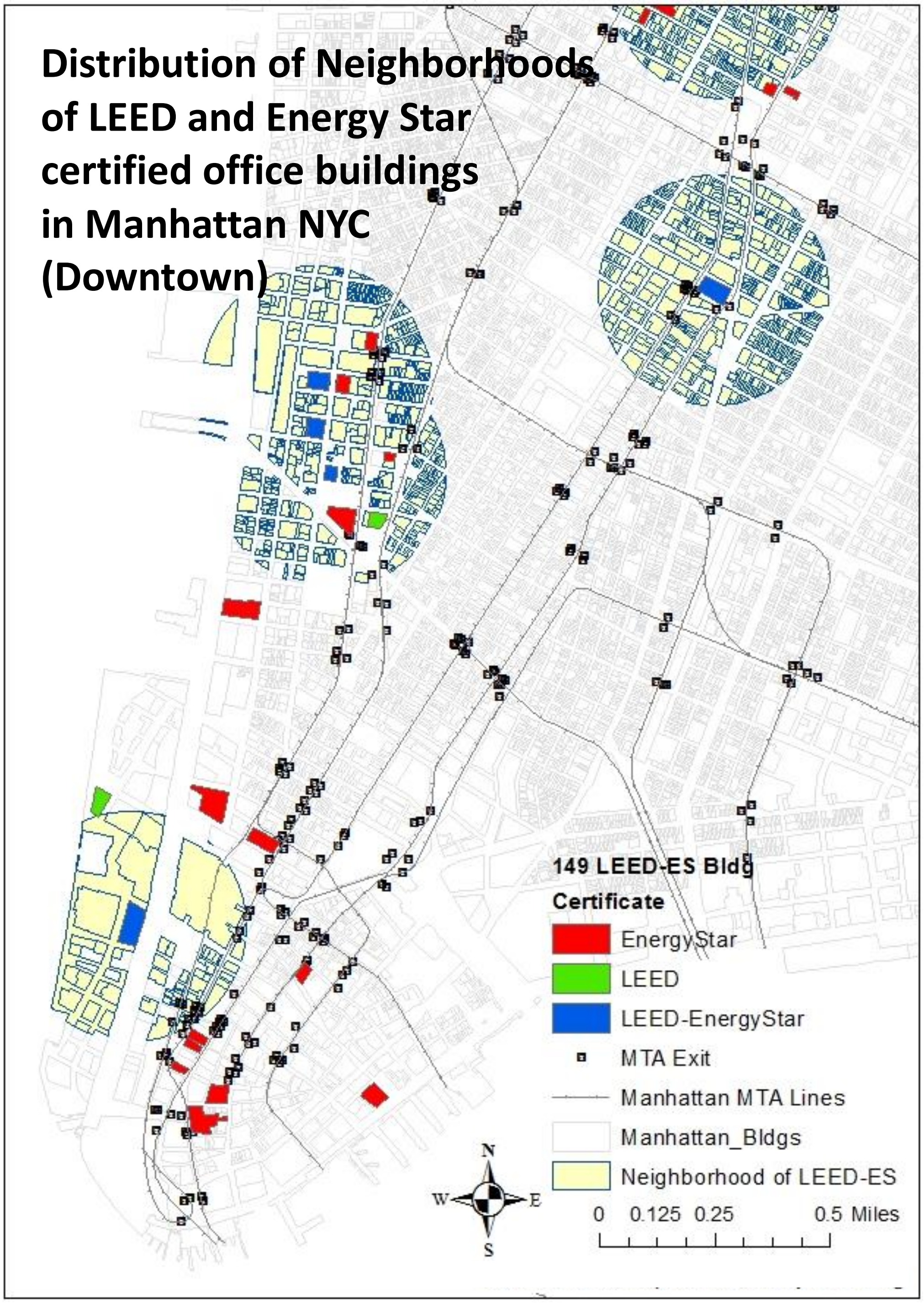

Figure 4.20. Distribution of neighborhood of LEED and Energy Star certified office building in Manhattan NYC (Downtown)

Of the 171 LEED and/or Energy Star certified office buildings in Manhattan, 149 were selected for inclusion in this study. The population was screened based on the congruousness of the available data to maintain consistency in this research after integrating the information provided by USGBC and EPA with the geographic information provided by the NYC's DCP because of the slightly different information for LEED and/or Energy Star certified office buildings provided by each organization. Therefore, the LEED and/or Energy Star certified office buildings in Manhattan were sorted and selected by matching the Borough-Block-Lot (BBL) number to ensure the consistency of the specific data information for the screened population group. The information on buildings with LEED and Energy Star certification was provided by the USGBC and the EPA, respectively, and the geographic information was provided by NYC's DCP. Most of the 149 LEED and/or Energy Star certified office buildings in Manhattan NYC 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. The neighborhood of each of the certified office buildings was taken to be the geographical boundary of neighborhood area for each LEED and/or Energy Star certified office building. The proximity to the closest subway entrance of the buildings in each neighborhood was also taken into account because the walkable distance from a building to the closest subway entrance was expected to have a major impact on the property value of that building. As shown in the previous figures, 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 did not have any subway entrances within their neighborhood boundary, as shown in Figures 4.21, 4.22, and 4.23. 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 the online Google Map service, the greatest straight-line distance between the 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 4.23). 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 three neighborhoods that lacked subway entrances in their neighborhood areas were described by comparing the difference of both distances, pedestrian walk route distance and straight-line distance, to the closest subway entrance from the furthermost building in their neighborhoods (Figures 4.21, 4.22, and 4.23).

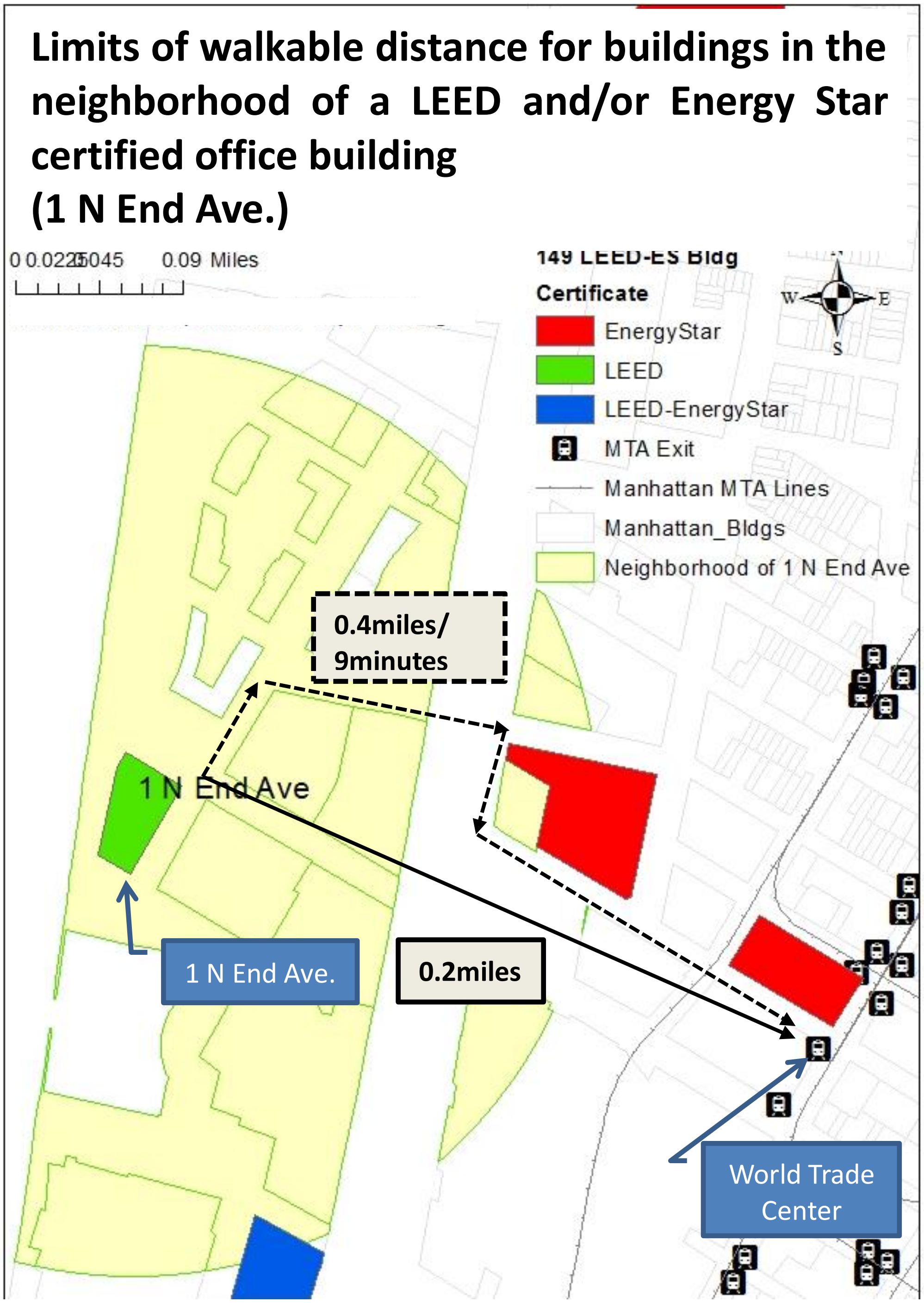

Figure 4.21. No subway entrance in the neighborhood of 1 N End Ave.

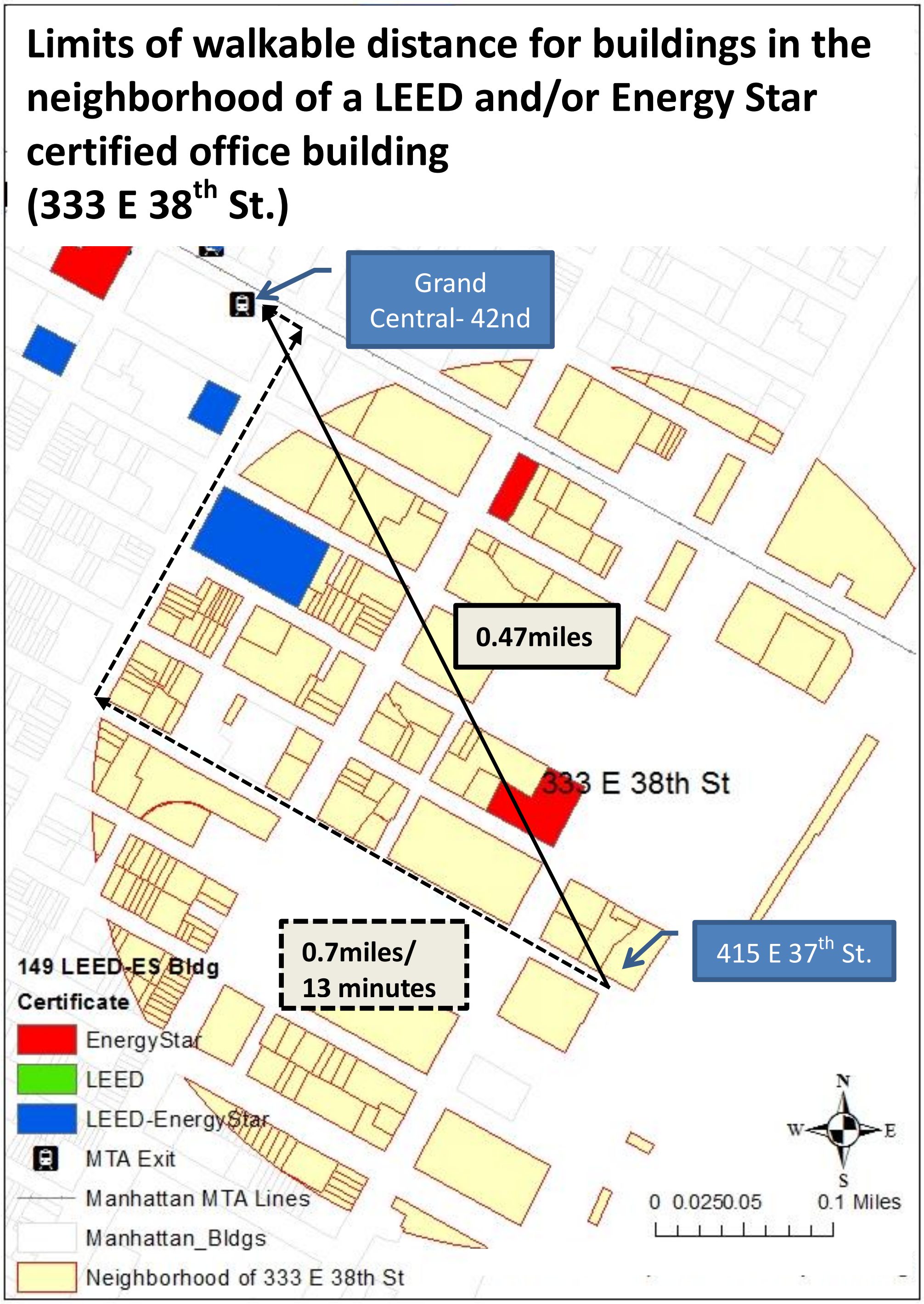

Figure 4.22. No subway entrance in the neighborhood of 333 E 38th St.

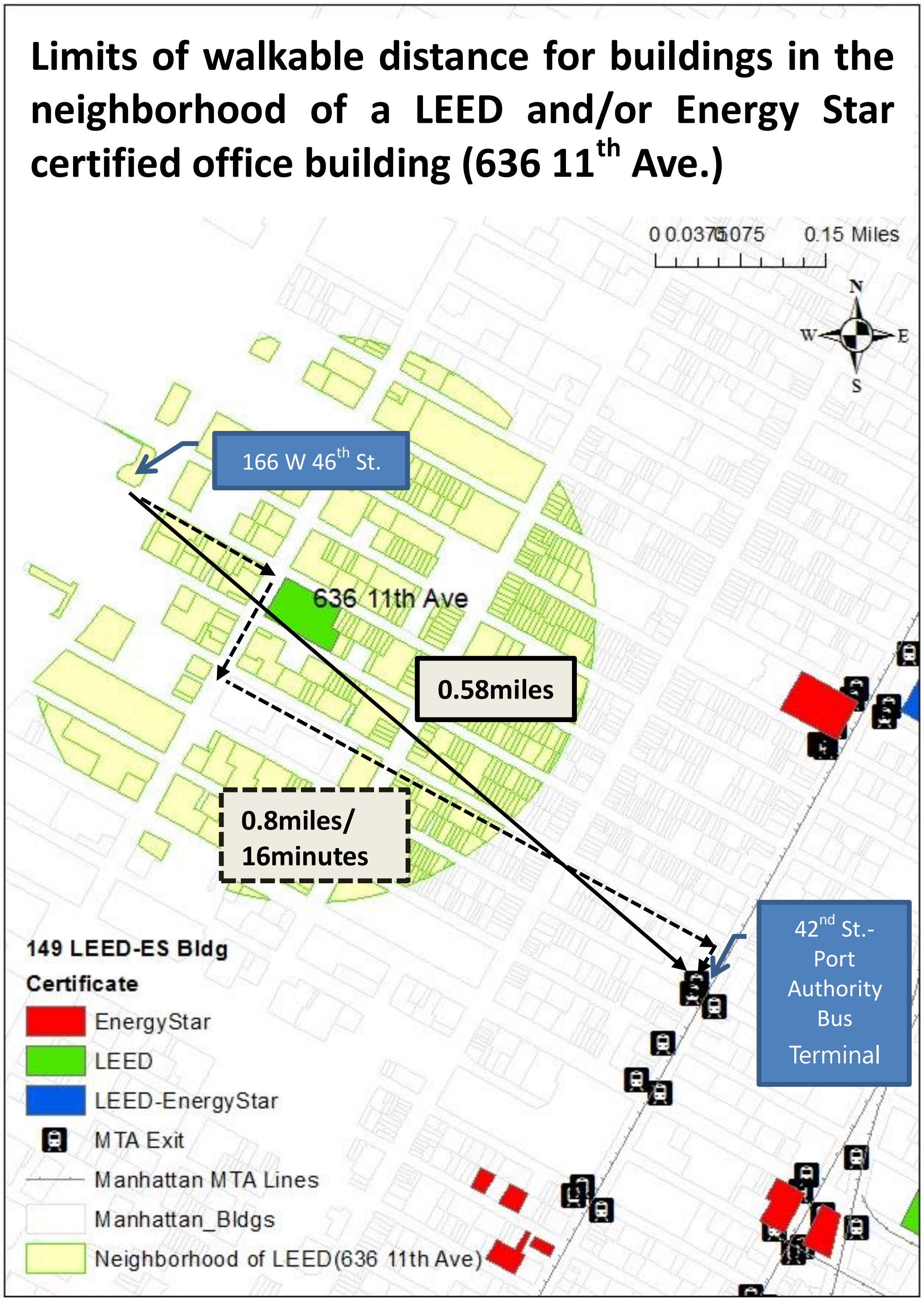

Figure 4.23. No subway entrance in the neighborhood of 636 11th Ave.

As there was such a high density of LEED and/or Energy Star certified office buildings in the midtown area of Manhattan, some LEED and/or Energy Star certified office buildings were included in the neighborhood area of other LEED and/or Energy

Star certified office buildings, as shown in Figure 4.24.

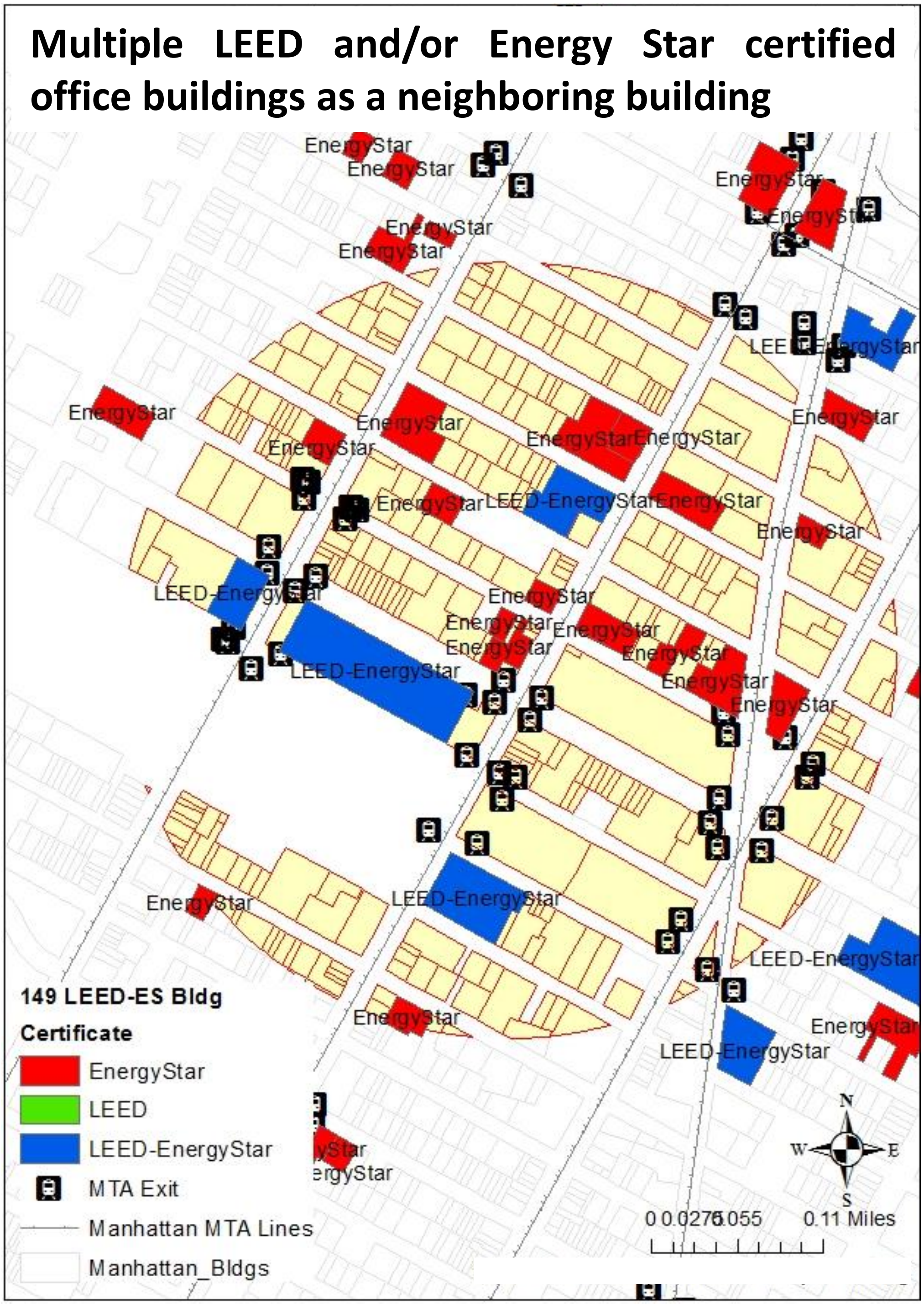

Figure 4.24. LEED and/or Energy Star certified office buildings in the neighborhood of Energy Star only certified office building

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 status of its LEED and/or Energy Star certification indirectly via general economic variables such as price and rent values, ownership-tenancy ratio, transporation availability and costs, and utility costs, all of which were considered annually when estimating the market value of buildings in NYC by NYC's DOF (New York City Department of Finance and Department of Investigation, 2004). 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 (Miller et al. 2008; McGraw-Hill Construction 2010; Eichholtz et al. 2010; Wiley et al. 2010; Suh et al. 2013). Consequently, the median market value of each building in the neighborhood included every direct or indirect impact from the internal and external features, including the changes in the market value of the LEED and/or Energy Star certified office building due to the achievement of LEED and/or Energy certification.

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. Figure 4.25 shows a case of overlapping areas of neighborhood of three different certified office buildings. This figure reveals three overlapping areas: one overlapping area includes LEED only, Energy Star certification only, and LEED and Energy Star certifications, and two overlapping areas are created by the neighborhoods of LEED only and Energy Star only 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.

Figure 4.25. Overlapping areas of neighborhoods of LEED and/or Energy Star certified office buildings

Note. The significance of numbers used to label the overlapping areas is as follows: 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)

Rather than individual buildings in the neighborhood of a LEED and/or Energy Star certified building, this research focused on the whole neighborhood area by considering the median unit market value of buildings in the neighborhood of a LEED and/or Energy Star certified office building to examine the impact of a LEED and/or Energy Star certified office building on the surrounding neighborhood in the socio-economic standpoint through the numerical results of statistical analyses.

The results of the geographical approach method applied 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: LEED certification only, Energy Star certification only, and LEED and Energy Star certifications. The 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 the number of LEED and Energy Star certified office buildings, 46. The results indicated that the average number of buildings in the neighborhood of each LEED and/or Energy Star certified office buiding, namely those located within a quarter-mile-radius-circle, was 521. The average number of buildings in the neighborhood for the three different combinations of LEED and/or Energy Star certification had fairly similar mean values for Energy Star certification only and both LEED and Energy Star certifications, but the mean number of buildings in the neighborhood of the LEED only certified office buildings was substantially lower. Table 4.6 shows these values for the study neighborhoods.

Table 4.6. 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 selected based on the results of the geographical analysis. The numerical data set for the statistical analysis was created by exporting the integrated information from ArcGIS 10.1 which supported the CSV format, one of the available formats for utilizing R-Project 3.0.2. Based on the objectives of this research, the data sets included the major characteristics of LEED and Energy Star certifications such as LEED certification coverage and LEED certification levels and the unit market value for 149 LEED and/or Energy Star certified office buildings in Manhattan NYC. The LEED certification coverage indicated that the certification was achieved for a whole office building or parts of office buildings, and LEED certification levels consisted of four different levels based on the points a LEED certified office building can earn, ranging from Certified through Platinum. The median unit market value of buildings in the neighborhood surrounding each LEED and/or Energy Star certified office building was also included in the data sets. 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

A descriptive analysis generally presented the data characteristics and the trends related to core specific information from the original data set. The starting point for 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 (every office building with LEED certification) were shown in Tables 4.7 to 4.8 and Figure 4.26 below. The data presented in Table 4.5 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. Table 4.8 presented the changes in LEED certification levels with the percentage of each LEED certification level. In the early stage of this research period, 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 the first two research years, 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 in Table 4.6 and Figure 4.26 rose from 0 to 2 during this study period, 2007 through 2013. However, the very low numbers involve limit the utility of regression analysis for the buildings certified at the LEED Platinum level for this study.

Table 4.7. 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 4.8. 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 4.26. Proportion of LEED certification levels in the sample group

Five descriptive analyses were performed for this research. 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 4.9. 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 consistently 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, where 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. In addition, Table 4.9 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 4.26 also 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 between 2007 and 2013, with both values increasing steadily throughout the research period.

Table 4.9. Median unit market values ($/sq-ft) of LEED and/or Energy Star certified office buildings over time

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

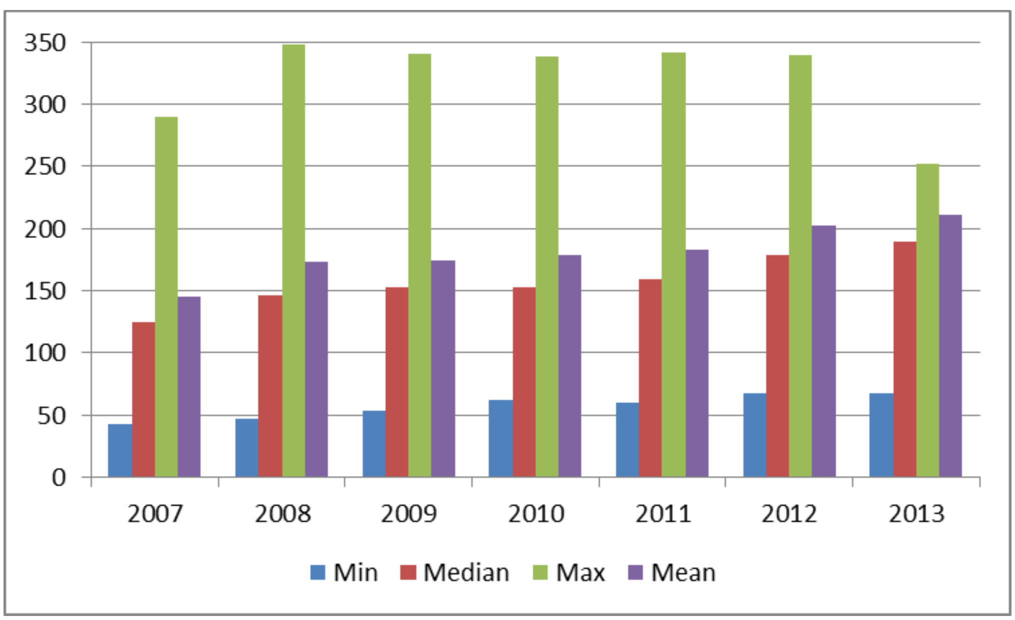

Figure 4.27. Trends in neighborhood median unit market values ($/sq-ft)

Changes in the number of LEED and/or Energy Star certified office buildings are shown in Figure 4.28. The graphs clearly illustrate 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 to note that the numbers of Energy Star only and LEED and Energy Star certified office buildings both decreased in 2013. Buildings with Energy Star certification are required to re-evaluate their Energy Star certified building performance based on the actual building performance data of energy and water consumption during the certified year in order to extend 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. Table 4.10 shows clear trends in the Energy Star certification status from 2007 through 2013. In particular, 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 on their website, but it was likely due to the following three main 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.

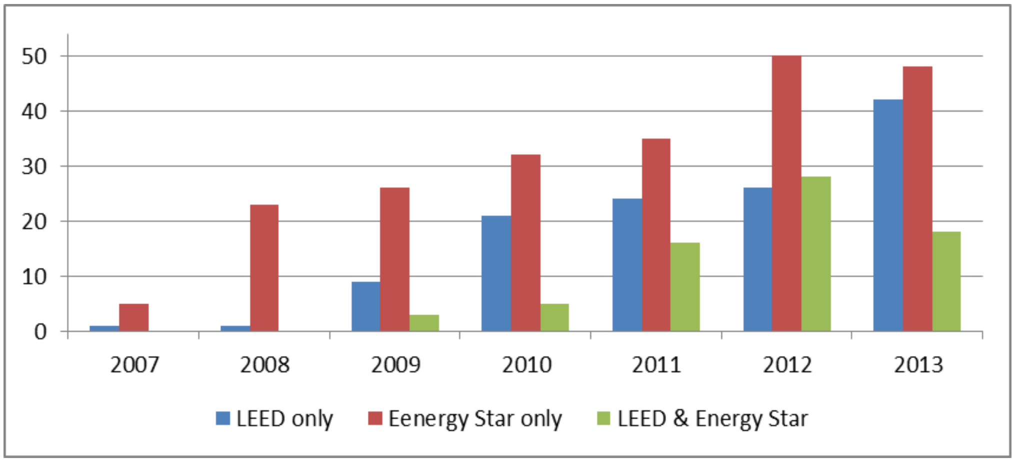

Figure 4.28. Number of LEED and/or Energy Star certified office building in Manhattan NYC

Table 4.10. The annual number of buildings achieving Energy Star certification from 2007 through 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, which could be either linear or non-linear, and it was thus necessary to comprehend the pattern of the correlation between two variables to determine the appropriate regression methods to be utilized for the further analysis. Therefore, the pattern between these two variables was analyzed based on the distribution of points using Microsoft Excel. The results indicated that the correlation of the two variables for each research year from 2007 through 2013 had a linear correlation, as shown in Figure 4.29.

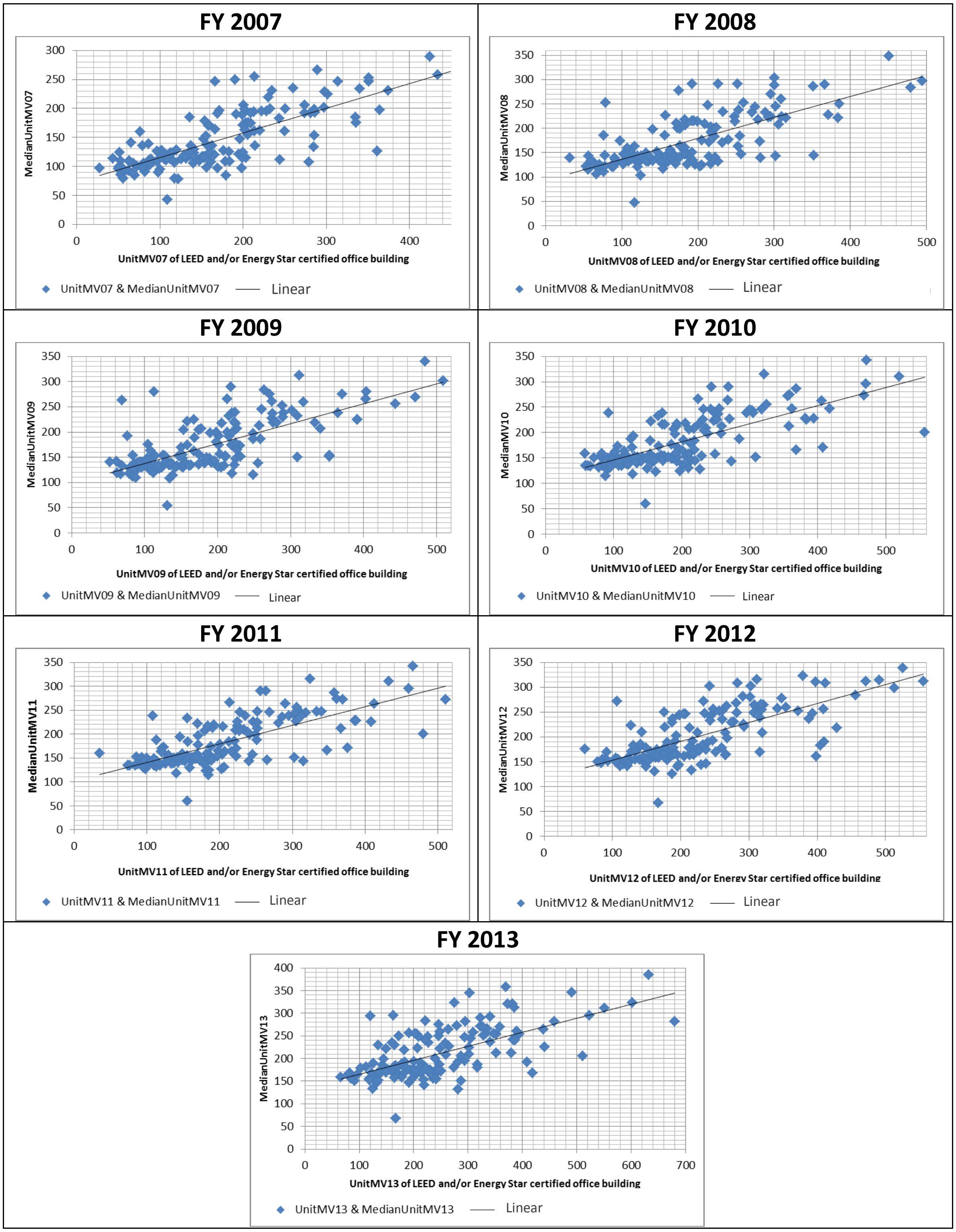

Figure 4.29. Linear correlation between the unit market value of LEED and/or Energy Star certified office building ($/sq-ft) and that of median unit market value of buildings in neighborhood ($/sq-ft) from 2007 through 2013

The median unit market value of buildings in the neighborhood of a LEED and/or Energy Star certified office building played a role as a dependent variable in this research and the achievement of LEED or Energy Star certification, LEED certification level, and the coverage of LEED certification (either part of the building or the whole building) were the independent variables shared by all linear mixed effect models to evaluate the correlation between the independent variables and the dependent variable. As mentioned earlier in Chapter 3, the unit market value of a LEED and/or Energy Star certified office building already takes into account the building characteristics when appraised by NYC's DOF. Therefore, the building's major physical characteristics were not considered in this analysis as they were not relevant to the purpose of this research.

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. It was necessary to find the most appropriate equation among the four hedonic price model equations that yielded the best R^2 value. Here, 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 from 2007 through 2013. Table 4.11 presents the results of the R^2 value for each of the four hedonic price model equations for 2011 as an example.

Table 4.11. 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 the need for any further data transformation, and the fundamental hedonic price model equation could be presented as follows:

Formula: 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. The processes were as shown below.

- Linear mixed effect model for achieving LEED and/or Energy certification from 2007 through 2013
- Linear mixed effect model for LEED certification level from 2007 through 2013
- Linear mixed effect model for LEED certification coverage from 2007 through 2013

1) 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:

Formula: 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, in particular, had a much higher impact than the other three independent variables. The specific coefficients and p-values for each independent variable are shown in Table 4.12.

Table 4.12. 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

According to the results shown in Table 4.10, 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 X Unit market value of LEED and/or Energy Star certified office building + 20.7178 X (LEED certification achievement) + 6.9597 X (Energy Star certification achievement) + $\alpha_0 + \alpha_1 b$,

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

2) Linear mixed effect model for the LEED certification level

The LEED certification provided four different certification levels for LEED certified office buildings, ranging from the Certified level to the Platinum level, and 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.

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

The results for this model are summarized in Table 4.13. The results indicated that all levels of LEED certification were significant because all the p-values for the independent variables were lower than 0.05. Furthermore, the result for the Platinum level of LEED certification was particularly interesting, as this had the only negative value among all the independent variables and indicated that the Platinum level of LEED only or LEED and Energy Star certified office buildings actually 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, which all had a positive impact on their neighborhoods. Based on this result, 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 X Unit market value of LEED only or LEED and Energy Star certified office building + 16.8306 X (LEED Certified level) + 22.7695 X (LEED Silver level) + 23.6624 X (LEED Gold level) − 39.8840 X (LEED Platinum level) + $\alpha_0 + \alpha_1 b$,

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

Table 4.13. 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

3) 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:

Formula: 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 all of the building. The results for this model indicated that all the independent variables were significant because all the p-values for the independent variables are below 0.05. This result also indicated that all the independent variables had a positive impact on the median unit market value of buildings in the neighborhood, and that LEED certification for the whole building had a more powerful impact on the dependent variable than the certification for part of the certified building based on the results of previous research in Chapter 3. The specific results are shown in Table 4.14.

Table 4.14. 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

According to these results, the linear mixed effect model equation could be expressed as follows:

Median unit market value of buildings in the neighborhood = 115.4628 + 0.3131 X Unit market value of LEED certified office building + 21.0827 X (LEED certification for the *whole building) + 15.3293 X (LEED certification for part of the building) +* $\alpha_0 + \alpha_1 b$*,*

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

- Model Validation

It was necessary to validate the three numerical models which were obtained through the statistical analysis. The dependent variable was the median unit market value of neighborhood of each LEED and/or Energy Star certified office building for all models, and the independent variables were selected for each model among the three measurements; the unit market value of LEED and/or Energy Star certified office building, the achievement of LEED and/or Energy Star certification, the LEED certification level, and the LEED certification coverage. The model validation 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 results 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.*

H_1*: The null model is not true.*

1) Linear mixed effect model for the effect of the unit market value of LEED and/or Energy Star certified office building and the LEED and/or Energy Star certification on the median unit market value of neighborhood of the certified office building

The result of LRT was 783.6022, and the p-value indicated that the value was significant because the p-value was smaller than 0.0001. The values of AIC (Akaike Information Criterion) and BIC (Bayesian Information Criterion) for this fitted model were smaller than the values of both criteria for the null model, indicating that H_0 was rejected and the fitted model was statistically more significant than the null model.

2) Linear mixed effect model for the effect of unit market value of LEED and/or Energy

Star certified office building and the LEED certification level

The LRT showed that the result was 757.26 with a significant p-value which was smaller than 0.0001. Moreover, the result of LRT indicated that this fitted model was statistically better than the null model because the values of AIC and BIC for the fitted model were smaller than the values of both criteria for the null model.

3) Linear mixed effect model for the effect of unit market value of LEED and/or Energy Star certified office building and the LEED certification coverage

The LRT showed the result was 680.4387 and the p-value was also smaller than 0.0001. The values of AIC and BIC indicated that this fitted model was better than the null model because the fitted model had smaller values of AIC and BIC than the null model.

Discussion 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 from an economic standpoint 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, such as LEED certification level and coverage, did 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 in terms of median unit market value of buildings in the neighborhood surrounding the certified office building were very similar, a relatively lower value than other independent variables. The achievement of LEED and/or Energy Star certification also provided a positive boost for neighborhood unit market values in general, although the strength of this positive impact differed significantly between the LEED certification for the data set, and the Energy Star certification. These results demonstrated that in general, LEED certification had a more positive impact on neighborhood's median unit market value than Energy Star certification, and that except for the Platinum level, every LEED certification level and all LEED coverages had a positive impact on median unit market values for their neighborhood. Only the Platinum level of LEED certification appeared to exert a strong negative impact on unit market values in the neighborhood in this data set. Although the p-value for the Platinum level of LEED certification was satisfied, the number of LEED Platinum certified office buildings was too small to accept the results for the coefficient value from a statistical viewpoint, hence more research is required to verify the coefficient value for LEED Platinum certified office buildings by including a greater number of LEED Platinum certified office buildings in future studies. Moreover, the result of LEED certification coverage for part of the building in this research did not support the findings of a previous chapter which reported that the P-value of LEED certification for part of the building was not significant. To resolve this conflict, 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 and LEED certification for only part of a building in the near future.

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, defined in terms of the walkable distance, 0.25 miles, in the research area, Manhattan, NYC, for the study period, 2007 through 2013. This finding suggests that these models could be applied to estimate the previous or current effect of LEED and/or Energy Star certified office buildings on the median unit market value of buildings in their neighborhoods from an economic standpoint for the local real estate market and local community in a metropolitan city with similar internal and external environmental conditions to those pertaining 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.

Based on these research outcomes, the following limitations of this study have been identified: 1) the use of a single, highly specific, geographical real estate market, Manhattan, NYC, 2) the limited number of LEED and/or Energy Star certified office buildings for each LEED certification level and coverage without considering any changes in their type of LEED certification, 3) the use of the median unit market value of buildings in the neighborhood of LEED and/or Energy Star certified office building rather than unit market values for individual buildings, 4) the potential impact of a national economic recession on the overall natural real estate market trends in Manhattan NYC over time; and 5) only a limited consideration was given to physical building features and external features in the existing environment that were known to be directly related to property economic values.

Future studies could build on these findings to develop a firm foundation for research in this area. For example, this research utilized median unit market values of buildings in the neighborhood rather than those of individual buildings, which limited to some extent efforts to highlight the specific impact of LEED and/or Energy Star certification including the effect of any change in the versions of LEED certification for buildings in the neighborhood. Second, although here the neighborhood was taken to be the area within the walkable distance of a certified building, it might be helpful to divide the neighborhood into several smaller parts with similar environmental conditions and thus reduce the effect due to unexpected external features in the existing environment.

Third, different proximities to LEED and/or Energy Star certified office buildings were likely to have a different impact on individual buildings in each neighborhood, and this was an area for further study. Finally, this research looked at the current effect of LEED and/or Energy Star certification on the median unit market values of buildings in the neighborhood rather than trying to predict future changes in these values as a result of both certifications. A study for the prediction of unit market values caused by the impact of the features of green certifications or other environmentally-friendly neighborhood features would be of great value for both the real estate market and advocates of green certified building. Consequently, although this research suffered from some limitations, it provides a sound approach first step for future efforts to examine and quantified the spillover economic effects of LEED and/or Energy Star certified office buildings for the economic benefits of their neighborhoods in the real estate market. Moreover, this research provides a useful foundation for future research into the socio-economic impact of LEED and/or Energy Star certified buildings on their neighborhoods based on local property values and other socio-economic measurements. As such, it represents a valuable contribution to research into the effects of green building certifications on local real estate markets and local economies.

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References

Appraisal Institute (2002). The Dictionary of Real Estate Appraisal, 4th Edition, Appraisal Institute, Chicago, IL.

Aydin, R., Crawford, E., and Smith, B. A. (2010). Commercial Development Spillover

Effects Upon Residential Values, Southwestern Economic Review, http://www.ser.tcu.edu/2010/SER2010-Aydin-et-al-47-62.pdf, (accessed August, 30, 2013).

Bloom, G. F., Weimer, A. M., Fisher, J. D. (1982). Real Estate, 8th Ed., John Wiley & Sons, New York.

Booz Allen Hamilton (2008). Green Jobs Study, http://www.usgbc.org/ShowFile.aspx?DocumentID=6435, (accessed March 10, 2012).

Boyce, B. N. (1984). Real Estate Appraisal Terminology, Ballinger Publishing Company, Cambridge, MA.Chang, K., and Chou, P. (2010). Measuring the influence of the greening design of the building environment on the urban real estate market in Taiwan, *Journal of Building and Environment*, 4S, 2057-2067.

Can, A. (1992). Specification and estimation of hedonic housing price models, *Journal of Regional Science and Urban Economics*, 22, 453-474.

Chang, K., and Chou, P. (2010). Measuring the influence of the greening design of the building environment on the urban real estate market in Taiwan, *Journal of Building and Environment*, 4S, 2057-2067.

Chun, B., Guldmann, J. M., and Seo, W. (2011). Impact of Multi-dimensional Isovist on Commercial Real Estate Values in CBD Area Using GIS, *Journal of Seoul Studies*, 12(3), 17-32.

Cypher, M. L., and Hansz, J. A. (2003). Does assessed value influence market value judgments? *Journal of Property Research*, 20(4), 305-318.

Dermisi, S. (2009). Effect of LEED Ratings and Levels on Office Property Assessed and Market Values, *Journal of Sustainable Real Estate*, 1(1), 23-47.

Dill, J. (2003) Transit use and proximity to rail – Results from large employment sites in the San Francisco, California, Bay Area. *Transportation Research Record* 1835: 19–24.

Dunse, N., and Jones, C. (1998). A hedonic price model of office rents, *Journal of Property Valuation and Investment*, 16(3), 297-312.

Eichholtz, P., Kok, N., and Quigley, J. M. (2010). Doing Well by Doing Good? Green Office Buildings, *American Economic Review*, 100(5), 2492-2509.

Epley, D. R., and Rabianski, J. (1981). Principles of real estate decisions, Addison-Wesley Publishing Company, Inc., Philippines.

Eply, D. R., Rabianski, J. S., and Haney, R. L. JR. (2002). Real Estate Decisions, Thomson Learning, Cincinnati, Ohio.

Federal Highway Administration. (2002) Toolbox for regional policy analysis, http://www.fhwa.dot.gov/planning/processes/tools/toolbox/, (accessed November 22, 2013).

Fisher, J. D., Geltner, D. M., and Webb, B. R. (1994). Value Indices of Commercial Real Estate: A Comparison of Index Construction Methods, *Journal of Real Estate Finance and Economics*, 9, 137-164.

Friedman, J. P., Harris, J. C., and Lindeman J. B. (2013). Dictionary of Real Estate Terms, Barron's Educational Series, Inc. Hauppauge, NY.

Fuerst, F., and McAllister, P. (2011). Green Noise or Green Value? Measuring the Effects of Environmental Certification on Office Values, *Journal of Real Estate Economics*, 39(1), 45-69.

Harris County Appraisal District (2009). Guide to understanding the property tax process. http://www.hcad.org/Help/Process/Guide.asp, (accessed November 2, 2013).

Hinshaw, M. (2012). Urban walkability: the new driver in real estate values. http://crosscut.com/2012/05/29/real-estate/108851/hinshaw-public-spaces/, (accessed on Nov 21, 2013).

Hough, D. E., and Kratz, C. G. (1983). Can "Good" Architecture Meet the Market Test?, *Journal of Urban Economics*, 14, 40-54.

Hui, E. C. M., Chau, C. K., and Law, M. Y. (2007). Measuring the neighboring and environmental effects on residential property value: Using spatial weighting matrix, *Journal of Building and Environment*, 42, 2333-2343.

Kanemoto, Y. (1997). Measurement of Development Benefits and the Hedonic Approach, Socioeconomic Evaluation of Road Investment Projects, 120-131, Keizai Inc, Tokyo, Japan.

Kang, K. and Kim, S. (2011). Analysis of the Elasticity of Loss Amount by Accident Types using Linear Mixed Effect Model, *Journal of Korea Insurance Research*, 22(1), 3-32.

Kerstens, S. M., De Ridder, R., Hof, A., Alberts, J., Mulhall, D., and Dale, D. (2011). Towards eco effective sustainable sanitation for the city of Almere, *Journal of Water Practice and Technology*, 6(2).

Kim, C., Phipps, T. T., and Anselin, L. (2003). Measuring the benefits of air quality improvement: a spatial hedonic approach, *Journal of Environmental Economics and Management* 45, 24–39

Kim, K. and Son, J. (2011). Real Estate Economics, KU Smart Press, Seoul, South Korea.

Lee, J. (2010). Environmental economics, Pakyoungsa Publishing, Seoul, South Korea.

Lee, S., Lee, H., Son, J., and Choi, J. (2009). Developing Office Rent Model by Time-Series Analysis, *Journal of the Korea Real Estate Analysts Association*, 15(3), 5-17.

Leinberger, C. B. (2012). Now Coveted: A Walkable, Convenient Place. The New York Times http://www.nytimes.com/2012/05/27/opinion/sunday/now-coveted-a-walkable-convenient-place.html?_r=0, (accessed November 14, 2013).

Leinberger C. B. and Lynch P. (2014). Foot Traffic Ahead: Ranking Walkable Urbanism in America's Largest Metros. http://www.smartgrowthamerica.org/documents/foot-traffic-ahead.pdf, (accessed September 30, 2014).

Lin, Z., Rosenblatt. E. and Yao, V. W. (2009). Spillover Effects of Foreclosures on Neighborhood Property Values, *Journal of Real Estate Finance and Economics*, 38(4), 387-407.

Liu, Y., Zheng, B., Turkstra, J., and Huang, L. (2010). A hedonic model comparison for residential land value analysis, *International Journal of Applied Earth Observation and Geoinformation*, 12(2), 181-193.

Mansfield, S., Pattanayak, S. K., McDow, W., McDonald, R., and Halpin, P. (2005). Shades of Green: Measuring the value of urban forests in the housing market, *Journal of Forest Economics*, 11, 177-199.

Matthews, J. W. (2006). The Effect of Proximity to Commercial Uses on Residential Prices, A Dissertation, Georgia State University and the Georgia Institute of Technology.

McGraw-Hill Construction (2008). Global Green Building Trends – Market Growth and Perspectives from Around the World, Smart Market Report: Design and construction intelligence, McGraw-Hill Construction, New York.

Miller, N., Spivey, J., and Florance, A. (2008). Does Green Pay Off?, *Journal of Real Estate Portfolio Management*, 14(4), 385-398.

Nelson, J. P. (1980). Airports and Property Values: A Survey of Recent Evidence, *Journal of Transport Economics and Policy*, 14(1), 37-52.

New York City Department of Finance (2014), Determining Your Market Value, http://www.nyc.gov/html/dof/html/property/property_val_estimate.shtml, (accessed October 21, 2013).

New York City Department of Finance and Department of Investigation (2004), Joint Task Force charged with Eliminating Corruption in the Department of Finance's Real Property Assessment Unit, http://www.nyc.gov/html/dof/downloads/pdf/03pdf/task_force_report_final.pdf, (accessed October 1, 2014).

New York City Metropolitan Transportation Authority (2013), http://web.mta.info/nyct/facts/ffsubway.htm, (accessed October 23, 2013).

O'Donnell, P. T., and Maleady, E. L. (1975). Principles of Real Estate, Thomson Learning Publishing, Saunders, Philadelphia.

O'Sullivan, A. (2009). Urban economics 7th Ed., McGraw-Hill Companies, Inc., New York.

Oklahoma City Embark (2013). www.gometro.org/benefits, (accessed October 24, 2014).

Reichert, A. K. (2002). Hedonic Modeling in Real Estate Appraisal: The case of Environmental Damages Assessment, Real Estate Valuation Theory, Kluwer Academic, Boston.

Rood, T. (2000). Ped Sheds. San Francisco, CA: Congress of the New Urbanism.

Saphores, J., and Li, W. (2012). Estimating the value of urban green areas: A hedonic pricing analysis of the single family housing market in Los Angeles, CA, *Journal of Landscape and Urban Planning* 104, 373-387.

Scanlon, R., and Cohen, H. (2009). Assessing New York City's Property Tax-Yet Again, The Manhattan Institute's Center for Rethinking Development.

Scofield J. H. (2009a). Do LEED-certified buildings save energy? Not really . . ., *Energy Buildings*, 41(12), 1386-1390.

Seltman H. J. (2014) Experimental Design and Analysis, Chapter 15 Mixed Model, 357-378, http://www.stat.cmu.edu/~hseltman/309/Book/chapter15.pdf, (accessed March 24, 2014).

Sohn, D. W., Moudon, A. V., and Lee, J. (2012). The economic value of walkable neighborhoods, *Urban Design International*, 17(2), 115-128.

Song, K. (1999). The Study of Random Effects in Linear Mixed Model for the Analysis of Repeated Measures, Dissertation, Yonsei University, South Korea.

Spreckley, F. (1981). Social Audit: A Management Tool for Co-operative Working 1981, Beechwood College Ltd., Leeds, United Kingdom.

SPSS Inc. (2005). Linear Mixed-Effects Modeling in SPSS: An Introduction to the MIXED Procedure, Technical Report LMEMWP-0305.

Starkweather, J. (2010). Linear Mixed Effects Modeling using R, http://www.unt.edu/rss/class/Jon/Benchmarks/LinearMixedModels_JDS_Dec2010.pdf, (accessed March 23, 2014).

Suh, M., Pearce, A. R., and Kwak, Y. (2013). The effect of LEED certified building on the neighborhood market value in New York City, The 5th International Conference on Construction Engineering and Project Management, Jan 9-11, Anaheim, CA, USA.

The City of New York (2014). PlaNYC website: http://www.nyc.gov/html/planyc/html/about/about.shtml, (accessed November 31, 2013).

U.S. Environmental Protection Agency (2006). Summary of The Financial Benefits of Energy Star Labeled Office Buildings, EPA 430-S-06-003.

U.S. Environmental Protection Agency (2012). Top Cities with the Most Energy Star Certified Buildings in 2012, http://www.energystar.gov/sites/default/uploads/buildings/old/files/Top_cities_chart.pdf, (accessed November 30, 2013).

U.S. Environmental Protection Agency (2013). Energy Star Overview of 2012 Achievements, http://www.energystar.gov/ia/partners/publications/pubdocs/ES%20bifold%20031313%20FINAL%20for%20print%20rev.pdf?b5fb-2f46, (accessed August 20, 2013).

U.S. Environmental Protection Agency (2013). Energy Star Certified Buildings and Plants, http://www.energystar.gov/index.cfm?fuseaction=labeled_buildings.locator, (accessed on November 31, 2013)

U.S. Green Building Council (2013). The Green Building Information Gateway, http://www.gbig.org/places/4949, (accessed November 31, 2013).

WalkScore (2014). http://www.walkscore.com/NY/New_York (accessed October 2013).

Weinberger, R. R. (2001). Commercial property value and proximity to light rail: A Hedonic Price Application. Dissertation, University of California Berkeley, CA.

Wiley, J. A., Benefield J. A., and Johnson K. H. (2010). Green Design and the Market for Commercial Office Space. *Journal of Real Estate Finance & Economics*, 41(2), 228–243.

Zhang, Y. (2010). Residential Housing Choice in a Multihazard Environment: Implications for Natural Hazards Mitigation and Community Environmental Justice, *Journal of Planning Education and Research*, 30(2), 117-131.

Chapter 5

The Spillover Effect of Proximity to a LEED-Energy Star Certified Office Building on Neighborhood Market Values in New York City

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This paper will be submitted to *The Journal of Green Building* (XXXX 2015).

Abstract: This research focused on the spillover effect of LEED and/or Energy Star certification on the market values in the surrounding neighborhood depending on a building's proximity to a LEED and/or Energy Star certified office building. LEED and Energy Star certifications are designed to not only protect the natural environment and promote the quality of life but also to produce positive economic benefits for certified building stakeholders by reducing operating expense and increasing property values. The economic benefits of achieving LEED and/or Energy Star certifications are also expected to extend to other buildings in their immediate neighborhood to encourage growth mutually in the entire local real estate market. These economic benefits should also satisfy part of the triple bottom line of sustainability for these certifications. The objective of this research was therefore to identify any differences in the impact of a LEED and/or

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Energy Star certified office building on the median unit market value of buildings in the same neighborhood in New York City based on their proximities to the certified office building using both spatial (a Geographic Information System [GIS]) and statistical (the hedonic price model and the linear mixed effect model) approaches. The results suggest that a LEED and/or Energy Star certified office building does indeed have various spillover effects on the median unit market value of buildings in each sub-neighborhood depending on the proximity of each building to the LEED and/or Energy Star certified office building. However, although the specific characteristics of the LEED certification had an impact on the neighborhood economically, there was no specific pattern discernable when the median unit market values of buildings in sub-neighborhoods with five different proximities to the LEED and/or Energy Star certified office building were examined.

Introduction

Green certified buildings that incorporate features such as low energy or low water consumption are rapidly gaining widespread acceptance, and the public recognition of these achievements through green building certification is expected to advance objective evaluations of sustainability. The construction industry has therefore introduced several certification schemes, the most prominent of which in the United States (U.S.) were Leadership in Energy and Environmental Design (LEED) and Energy Star. These were designed to promote the reduction of negative environmental impacts which are directly related to the quality of human life and society. The hope is that certified buildings will provide positive economic benefits to not only LEED and/or Energy Star certified building stakeholders but also their neighborhoods and local community through achieving the green building certifications.

A number of researchers have examined the sustainability of LEED or Energy Star certifications by considering its triple bottom line of sustainability for both certifications in the environmental, economic, and social aspects. Since the triple bottom line of sustainability was first articulated by Freer Speckley in 1981, not only the contributions to environmental conservation issues and the quality of human life of LEED or Energy

Star certification have been investigated, but also the resulting economic benefits. Social or socio-economic benefits such as better public health, recreational facilities and landscapes, and an improved local real estate market have also been emphasized by several researchers. For example, Kerstens et al. (2011), and Suh et al. (2013) all supported the principle of the 3Ps, People, Planet, and Profits, which incorporated the triple bottom lines of sustainability. These researchers agreed that the 3Ps were interconnected, with Suh et al. (2013) in particular emphasizing the importance of ensuring individual residents and their neighborhoods share in the profits for mutual growth. Recent studies about the economic benefits of LEED and/or Energy Star certification to the certified buildings via rental rates, occupancy rate, sales price, and resale value rate also highlight the need for research into the spillover effects of LEED and/or Energy Star certification on the neighborhood in the immediate vicinity of the certified buildings from an economic standpoint.

The aim of this research is therefore to provide valuable evidence concerning the diffusion of the economic benefits of sustainability to neighbors and the surrounding local community due to LEED and/or Energy Star certification by quantifying the spillover effects of the LEED and/or Energy Star certification of office buildings in New York City (NYC), demonstrating that both the stakeholders of the certified buildings and their neighborhoods benefit, a win-win situation for the local real estate market.

Background

The spillover effects of proximity to the external features in the existing environment

Property values, which represent the value of a particular building to its owner through measures such as rental rates, unit sales price, resale value rate, and occupancy or vacancy rates are determined by the law of demand and supply in the actual real estate market (O'Donnell and Maleady 1975; Epley et al. 2002; O'Sullivan 2009). In general, the property values of a specific building are affected by several factors which consist of internal and external environmental features. In particular, the property value of a building could be affected by changes in the property values of other buildings in the neighborhood or in the same community, as well as other economic features (Epley and Rabianski 1981; Bloom et al. 1982; Epley et al. 2002). Numerous previous studies have investigated the impact of external environmental features on the property values of buildings located around the external environmental features. Nelson (1980), Weinberger (2001), Kim et al. (2003), Mansfield et al. (2005), Hui et al. (2007), Lin et al. (2009), Liu et al. (2010), Aydin et al. (2010), Chang and Chou (2010), Chun et al. (2011), Saphores and Li (2012), and Suh et al. (2013) reported a correlation between the property values of buildings and external environmental features; economic changes in property values in a specific area that had undergone a significant change in the neighborhood environment also had a correlation with the market value of a particular building. Specifically, these studies found that external environmental features that were directly or indirectly related to the quality of human life brought either a positive or negative impact on the property value of a particular building depending on the characteristics of external environmental feature. For instance, Nelson (1980) concluded that airport infrastructure systems made a negative impact on residential properties located around the airport as an external environmental feature due to the high airport noise levels. On the other hand, Weinberger (2001) found a positive impact due to proximity to public transportation on both residential and commercial property values in his research study area because public transportation, specifically light rail transit, improved accessibility to other areas. Table 5.1 describes the spillover effects of external environmental features on property values from an economic standpoint, as shown in previous studies.

Table 5.1. Spillover effects of external environmental features on property values

	Property type	**External environmental feature**	**Spillover effect**
Nelson (1980)	Residential	Airport	Negative spillover effect due to the high noise levels from the airport
Weinberger (2001)	Residential or Commercial	Light rail transit	Positive spillover effect due to improving the accessibility to another area
Kim et al. (2003)	Residential	Air quality improvement	Positive spillover effect due to improving the quality of human life
Mansfield et al. (2005)	Residential	Urban forests	Positive spillover effect due to improving the quality of human life

Table 5.1 (Continued). Spillover effects of external environmental features on property values

	Property type	External environmental feature	Spillover effect
Hui et al. (2007)	Residential	Sea view Green belt area Air quality Noise level Accessibility	Positive spillover effect due to improving the quality of human life
Lin et al. (2009)	Residential	Foreclosure	Negative spillover effect due to depreciating the community reputation
Liu et al. (2010)	Commercial or Residential	Land use	Positive spillover effect due to improving the quality of human life
Aydin et al. (2010)	Commercial or Residential	Commercial developments	Positive spillover effect due to improving the environmental conditions
Chang and Chou (2010)	Neighborhood	A building's green design	Positive spillover effect due to improving the environmental conditions
Chun et al. (2011)	Commercial	Visible space	Positive spillover effect due to improving the quality of human life
Saphores and Li (2012)	Residential	Urban green area	Positive spillover effect due to improving the quality of human life
Suh et al. (2013)	Commercial	Green building certification; LEED	Positive spillover effect due to improving the environmental conditions

Of particular interest for the previous studies in Table 5.1, both Lin et al. (2009) and Aydin et al. (2010) concluded that the spillover effects of the external environmental features they examined were affected by a building's proximity to these external environmental features. Lin et al. (2009) showed that the negative impact of a foreclosure on residential property values in the immediate vicinity of the foreclosure decreased with increasing distance and became insignificant for properties more than 0.9 km away, which corresponded to about 0.5 miles or 2,700 feet. Aydin et al. (2010) also noted the importance of proximity to the external environmental feature for property values in the neighborhood, concluding that the greatest positive spillover effect would be found within a 0.5 mile radius of the district's boundaries, after which the positive spillover effect would start to decrease. Chang and Chou (2010) and Suh et al. (2013) demonstrated that external environmental features such as nearby green buildings could provide a positive spillover effect on the surrounding area, possibly by boosting the community's reputation or improving local economic conditions.

As noted above, the proximity of an individual property to external environmental features is likely to be important because these external environmental features will exert a spillover effect on the economic value of a property assessed in an appraisal. Gelfand et al. (1998) contended that the qualities of a residential building, specifically any additional renovations it has received, its socio-economic condition, and its proximity to any amenities, played a tremendous role as proxies for the spillover effect because once constructed it would generally be fixed permanently in the same location. Tandon highlighted the importance of proximity, explaining that "If the house price is influenced by the location factors then there is a strong prospect that neighboring houses are also influenced by the same location factors" (2012, p.31). In other words, any changes in the property value of a particular building would be expected to have a knock-on effect[21] on neighboring buildings and be one of the determinant factors influencing buyers in the entire local real estate market. Geographical changes could also potentially play a central role in the values of comparable buildings in the same neighborhood under similar conditions (Jeong 2011; Tandon 2012). Tandon also pointed out that "The closer the neighbors are in space the greater is the price influence on the subject property …… Housing transactions are also known to be influenced by the prices of recently sold houses in the neighborhood" (2012, p.29 and p.31). Jeong (2011) concurred, noting that the market value of neighboring buildings included every surrounding external environmental condition, and the market value of neighboring buildings should therefore be included among the external environmental features of the subject property.

Changes in the property value of a LEED or Energy Star certified building

Several researchers have examined the impact of LEED or Energy Star certification on a building by measuring the resulting change in its property value as represented by

[21] The inevitable and indirect effect of an event or a circumstance on something in any aspect (Collins English Dictionary online version: http://www.collinsdictionary.com/dictionary/english/knock-on-effect, accessed October 5, 2014)

the certified building's rental rates, unit sales price, vacancy or occupancy rate, and resale value rate (McGraw-Hill Construction 2008; Miller et al. 2008; Eichholtz et al. 2010; Wiley et al. 2010; Fuerst and McAllister 2011). Suh et al. (2013) summarized the findings of these studies of the impact of LEED certification on a building's property value by comparing the LEED certified buildings to comparable non-certified buildings under similar conditions, reproduced as Table 5.2 below.

Table 5.2. Comparison of LEED and Energy Star certified buildings and comparable non-certified buildings applying 4 different metrics of property value

	Property type	Rental rates	Unit sales price rate	Occupancy rate	Resale value rate
Miller et al. (2008)	All types of property	LEED certification was about 20% (2006; 1Q)-50% (2006; 3Q) higher; Energy Star certification was about 0.5% (2005; 1Q)-9% (2007; 2Q) higher		LEED certification was about 0% (2006; 3Q)-4.7% (2005; 4Q) higher and 0.7% (2006; 2Q) lower; Energy Star certification was about 1% (2005; 2Q)-3.5% (2008; 1Q) higher	LEED certification was about 9.9% lower; Energy Star certification was about 5.3% higher
McGraw-Hill Construction (2010)	Commercial property	LEED & Energy Star certifications were 1% (retrofit and renovation for commercial property)-6% (new commercial property) higher		LEED & Energy Star certifications were 2.5% (retrofit and renovation of commercial property)-6.4% (new commercial property) higher	LEED & Energy Star certifications were 6.8% (retrofit and renovation of commercial property)-10.9% (new commercial property) higher
Eichholtz et al. (2010)	Office property	LEED certification was 6% higher; Energy Star certification was 6.5% higher		LEED & Energy Star certifications were 2.35% higher	LEED certification was about 11% lower; Energy Star certification was about 12.9% higher
Wiley et al. (2010)	Commercial property	LEED certification was 15.2-17.3% higher; Energy Star certification was 7.3-8.9% higher		LEED certification was 16.2-17.9% higher; Energy Star certification was 10-11% higher	
Fuerst & McAllister (2011)	Office property	LEED certification was 5% higher; Energy Star certification was 4% higher	LEED certification was 25% higher; Energy Star certification was 26% higher		

Note: The unique external conditions for each are specified in the appropriate reference, including geographical location, building size, building age, research period, etc.

Several detailed property benefits have been shown to accrue as a result of LEED and Energy Star certifications. For instance, Wiley et al. (2010) found that the Energy Star certified buildings in their study enjoyed a 7.3 to 8.9 percent premium on their rental rates, and there was at least a 15 percent (15.2 to 17.3 percent) premium on the rental rates for LEED certified buildings. In addition, Miller et al. (2008), McGraw-Hill Construction (2010), and Eichholtz et al. (2010) reported that the resale value rates of LEED certified buildings and Energy Star certified buildings were higher than those of non-certified buildings, and McGraw-Hill Construction (2010) also reported two different resale value rates based on the physical building status, namely whether it was a retrofit and renovation or a new build. In particular, McGraw-Hill Construction (2010) demonstrated that the resale value rate of a new building with LEED certification or Energy Star certification was about four percent higher than that of a retrofitted or renovated building with a certification. Fuerst and McAllister (2011) concluded that there was little difference between the positive effect of LEED certification and that of Energy Star certification on the rental rates and the unit sales prices. Specifically, LEED certification had one percent higher positive effect on the rental rates than Energy Star certification, but this was reversed for unit sale prices, with Energy Star certification having one percent higher positive effect than LEED certification. In general, the occupancy rate of LEED only and Energy Star only certified buildings was higher than that of non-certified buildings except for in the second quarter of 2006 in Miller et al. (2008)'s study. The same study revealed that this was the only point at which the occupancy rate of LEED only and Energy Star only certified buildings was lower than that of non-certified buildings, contravening the upward trend seen throughout the rest of their research period. Consequently, these studies showed that LEED and Energy Star certification generally affected the metrics of the building property value itself positively, and this positive impact of LEED and Energy Star certification on the building property value could encourage a synergistic effect between a particular building with LEED and Energy Star certification and its surrounding neighborhood through the spillover effect on the local real estate market.

Defining neighborhood area based on walkable distance

In the real estate market, demographic factors are major determinants for both buyers and sellers as external features in a building's existing environment because they have a significant effect not only on the target property but also on surrounding properties (Kim and Son 2011; Sohn et al. 2012). O'Sullivan (2009) suggested several reasons why the demographic factors might be important for office property values. For instance, increasing proximity to a central business district (CBD) still enhances the productivity of employees, even though the importance of proximity to a CBD is no longer as big a factor as it was a few years ago because of recent advances in communication technology that permit regular office activities to proceed without the need for offline face time, thus reducing production expenses. The higher population density in suburban areas supports a higher rental rates for office buildings; and the opportunity to conduct face-to-face meetings is related to the office rental rates because face-to-face meetings involve spending time and money to service providers' employees. These considerations combine to make the walkability, or the walkable distance, a core factor for buyers or tenants, especially for people looking for a residential property as they generally take into account the proximity between their work and living spaces. Haider and Miller (2007) and Kim and Son (2011) both reported that increasing distance from the CBD decreased both land and house prices and Abelson (1997) agreed, demonstrating that increasing distance from the CBD decreased both land and residential prices in Sydney, Australia. Leinberger (2012) also reported that home seekers would generally pay more for residential buildings in closer proximity to their work places and suggested that the average rental rates was increased by improved walkability, estimating that this added $9 per sq-ft for annual office rents, $7 per sq-ft for annual retail rents, $300 per month for apartment rents, and $82 per sq-ft for home values. Other researchers have also quantified proximities to destinations that were favored by commuters or pedestrians for their destinations, giving suggested walkable distances of between 0.2 miles and 0.3 miles, or between five and ten minutes. For instance, Ewing (1995) suggested 0.3 miles to be a good distance for a shopping center and 0.2 miles for a transit stop and the Federal Highway Administration (FHWA) (2002), Rood (2000), and Dill (2003) recommended 0.25 miles or five to ten minutes as an appropriate walkable distance for most purposes; Sohn et al. (2012) also suggested a walkable distance to be between 0.25 miles and 0.3 miles.

Due to the growing importance of walkable distance in the real estate market, the new metric “WalkScore” has been introduced to providing an online score for residential property values that takes into account their proximity to the types of amenities that residents frequently seek and consider essential in their neighborhood (Hinshaw 2012). In NYC, this includes, for example, the proximity to public transportation, especially Metropolitan Transportation Authority (MTA) subway entrances, which are an important external environmental feature in this metropolitan city because the subway is the busiest public transportation network and carried the highest number of commuters of any U.S. city, all of whom could foster more livable communities through their contacts with local businesses (NYC MTA 2013; Oklahoma City Embark 2013). Any subway entrances in Manhattan can be reached within a 15 minute walk from any geographical point within the borough of Manhattan, which is a source of satisfaction for commuters in NYC (NYC MTA 2013). Based on this reasoning, for this research a building’s neighborhood area was taken to be a circle with a radius equal to the walkable distance from the building of interest when measuring the spillover effect of a LEED and/or Energy Star certified office building on the median unit market value of buildings in its neighborhood area.

Property market values in New York City

The market value generally refers to the most probable price of a property in a competitive and open market under stable conditions with buyers and sellers who have sufficient knowledge and information of the property and serious intentions (Boyce 1984; Friedman et al. 2013). The market value can also be represented by the price of a transaction which has been completely and successfully finished to transfer the property ownership from a seller to a buyer (Boyce 1984). Generally, the market value is determined by the willingness of a buyer to pay and the willingness of a seller to accept a given price to the satisfaction of both sides (Sohn et al. 2012; Friedman et al. 2013).

New York City's Department of Finance (NYC's DOF) conducts an annual exercise to estimate the market value of every building in NYC's five boroughs, taking as its starting point the taxable value of individual properties, and is based on a fiscal year from July 1 through June 30 of the following year. It has been argued by several researchers that there is little realistic difference between the market value for calculating property tax and an actual transaction or sales price. Although Cypher and Hansz (2003), Aydin et al. (2010), and the Harrison County Appraisal District (HCAD) (2009) described the flaws of assessed value, the accuracy of actual sales prices, and the ensuing discrepancies with appraised values, Matthews (2006), Dermisi (2009), Zhang (2010), Aydin et al. (2010), and Kim and Son (2011) suggested a few reasons why estimated market value could be used instead of actual transaction or sales prices for the following reasons:

- It provides a useful approximation to willingness to pay for a residential property due to the comparable sales approach;
- It avoids the problem of the limited number of actual transactions or sales each year;
- It sidesteps the difficulty of obtaining actual transaction prices or actual sales prices;
- There is a good correlation between actual sales prices and tax appraisals;
- It is helpful to be able to link tax assessment values to other tax based government data; and
- Estimated market value affects the rental rates, which has a fundamental impact on determining the actual sales price.

Furthermore, NYC's DOF continually strives to enhance the realism of the estimated market values used, and adopts different approach methods for each tax class in order to estimate the market value and consider various internal and external environmental conditions, as shown in Table 5.3. It is important to note that the estimated market value did not impose any caps for increasing or decreasing price, just as actual sales prices or transaction price did not. The tax benefits, exemptions, and abatements are also reflected in the assessed value, which is based directly on the estimated market value and the tax. DOF then re-estimates the market value by applying an adjustment that utilizes the ratio of the most recent final assessment roll for the assessment roll option or a deduction of the appraised market value of land from the appraised market value of land and structure for the appraisal option. The market value estimated by NYC's DOF reduces the difference between the estimated market value and actual transaction price or actual sales price, and it is available to represent a reasonable estimate of the property value for all properties in NYC. Therefore, the estimated market value provided by NYC's DOF is a more appropriate data set for an academic research study than the actual transaction or sales prices, which would necessarily be incomplete and out of date.

Table 5.3. Approach utilized by NYC's DOF for each tax class

Tax class	Property type	Approach method	Descriptions
Class 1	1-2-3 unit residential property	Comparable sales approach	- Recent sales price of comparable properties in the neighborhood in previous three years
Class 2	Cooperatives and condominiums (more than three units)	Income and expenses approach	- Income and expenses from comparable properties[22] - Gross Income from annual Real Property Income and Expense (RPIE) filings - Net Income Capitalization[23] and Gross Income Multiplier (GIM)[24]
Class 3	Utility property and special franchise property	Cost approach	- Land value - Adding the construction / reproduction / replacement cost of the building - Considering the depreciation of the building value
Class 4	Office buildings, factories, stores, hotels, and lofts	Income and expenses approach	- Income and expense based on annual Real Property Income and Expense (RPIE) reports

Statistical Analyses Using the Hedonic Price Model and Linear Mixed Effect Model

Kanemoto (1997), Reichert (2002), and Lee (2010) recommend the hedonic price model as the most appropriate way to analyze environmental values using cross-sectional data. Can (1992) and Lee et al. (2009) concurred, pointing out that this was one of the models most commonly used to find the effect of neighborhood, including both socio-economic characteristics and physical features. It has also been widely used to analyze

[22] Only for "Large rental buildings"

[23] Net Income Capitalization requires calculating net income, which is the difference between the income and expenses of a particular property, in advance and then net income divided by the capitalization rate that is the expected rate of return based on the income from a building. This method is usually applied to "Large condos and cooperatives" that have 11 units or more.

[24] Gross Income Multiplier uses the GIM ratio between the market value of a property and its future gross income. The total income of property is calculated by multiplying the typical income per sq-ft from comparable rental properties by the total sq-ft of the building. This method is applied to "Small buildings" that have 10 units or fewer.

correlations in a real estate market because one of the strengths of the hedonic price model is that it allows researchers to select a group of characteristics from among the numerous heterogeneous characteristics that affect the property value directly or indirectly to serve as independent variables in the hedonic price equations in accordance with the precise objectives of their research (Hough and Kratz 1983; Fisher et al. 1994; Dunse and Jones 1998; Weinberger 2001; Chun et al. 2011; Kim and Son 2011). Taking advantage of this benefit of the hedonic price model, the features of a building's LEED and/or Energy Star certification were selected here as most appropriate for the purposes of this research.

The hedonic price model provides four different hedonic price model equations that can be used to transform data by selecting the option among the four that provides the best determinant coefficient (R^2) that gives the closest to a linear equation graph. The hedonic price model equations are as follows:

- Linear function: $p_i = a_0 + a_1 z_1 + \cdots\cdots + a_n z_n + \varepsilon_i$
- Log-linear function: $p_i = a_0 + a_1 log(z_1) + \cdots\cdots + a_n log(z_n) + \varepsilon_i$
- Semi-log function: $log(p_i) = a_0 + a_1 z_1 + a_2 z_2 + \cdots\cdots + a_n z_n + \varepsilon_i$
- Log-log function: $log(p_i) = a_0 + a_1 log(z_1) + \cdots\cdots + a_n log(z_n) + \varepsilon_i$

Note. p_i: a value of response variable, a_p: coefficient, z_p: explanatory variables, ε_i: an error term, where i = {1,…, n} and n is the number of subjects in a data.

However, the hedonic price model suffers from a major limitation for this type of research, namely time. The hedonic price model focuses on a specific point of time when analyzing the effect of neighborhood characteristics, so the hedonic price model cannot be applied to data sets that vary over time. In such situations it is necessary to utilize the linear mixed effect model to address these limitations. In general, the linear mixed effect model is applied to examine changes in the market value of neighborhood characteristics over time. Both fixed effects, which are explanatory variables for the response, and random effects, which are varied by the subjects or the groups, are included in a linear mixed effect model. Fixed effects exist for all possible category values, while random effects appear when there is only a population or a sample for a possible category value. Therefore, a linear mixed effect model was useful for analyzing repeated measure data and cross-sectional data in multiple research fields instead of the hedonic price model (Song 1999; Starkweather 2010; Kang and Kim 2011; Seltman 2014). Since examining the same subject over time or for changing experimental or observational conditions produces numerous responses measured during different time periods or repeatedly over time, traditional repeated measures such as ANOVA and regression models are only of limited use for fitting models to longitudinal or repeated-measures data (Seltman 2009; West et al. 2007). It is possible, however, to estimate the random intercept for each subject, control correlated data, and deal with unequal variances by using a linear mixed effect model (SPSS 2005). The model can also be used to infer not only the fixed effects that are the primary interest but also random effects that are not the primary interest with a small set of levels (Song 1999; Seltman 2014). The fundamental equation of linear mixed effect model is as follows:

$$y_{ij} = \beta_1 x_{1ij} + \beta_2 x_{2ij} \ldots \beta_n x_{nij} + b_{i1} z_{1ij} + b_{i2} z_{2ij} \ldots b_{in} z_{nij} + \varepsilon_{ij}$$

Note. β_n: Fixed effect coefficients, i: the i-th subject (unit of analysis), x_{nij}: Fixed effect variables for observation j in group i, b_{in}: Random effect coefficients, z_{nij}: Random effect variables, ε_{ij}: the error for case j in group i

Problem statement

Numerous researchers have studied the effects of LEED or Energy Star certification from various standpoints, and they generally found a positive impact on the property value of a certified building (McGraw-Hill Construction 2008; Miller et al. 2008; Eichholtz et al. 2010; Dermisi and McDonald 2011; Fuerst and McAllister 2011). Other researchers have also examined the spillover effects of external features in existing environments on local property values (Nelson 1980; Weinberger 2001; Kim et al. 2003; Mansfield et al. 2005; Hui et al. 2007; Lin et al. 2009; Liu et al. 2010; Aydin et al. 2010; Chang and Chou 2010; Chun et al. 2011; Saphores and Li 2012; Suh et al. 2013). Both Jeong (2011) and Tandon (2012) pointed out that the economic benefits would be expected to be one of the determinant factors for buyers and sellers and could potentially play a role in setting the prices for comparable buildings of a similar type in the same neighborhood in a real estate market. In particular, the proximity to the subject property and the spillover effect on the economic benefits of its surrounding neighborhood due to the subject property have been shown to be proportional to each other (Lin et al 2009; Aydin et al. 2010).

These studies all suggest that a closer study of the effect of LEED and/or Energy Star certification as an external feature in an existing environment on market values in the neighborhood would be timely to support a part of the sustainability of LEED and/or Energy Star certification from an economic standpoint using the concept of spillover effects for a win-win approach. The hypothesis guiding the current study posits that the various economic spillover effects of a LEED and/or Energy Star certified office building on the buildings in its vicinity depend on their proximity to the LEED and/or Energy Star certified office building. Therefore, this study examined the difference in the spillover effect for neighborhood buildings with different proximities to the LEED and/or Energy Star certified office building for buildings in the neighborhood. For the purposes of this study, a neighborhood was defined in terms of the walkable distance from a socio-economic standpoint. The findings of this study would enable researchers to investigate more closely the diffusion of sustainability benefits from LEED and/or Energy Star certification to other buildings in the neighborhood based on the following research question: What is the spillover effect of a LEED and/or Energy Star certified office building in New York City (NYC) on the median unit market values of buildings in the neighborhood with different proximities to the certified building?

Methodology

Study area

One of the most vibrant metropolitan centers in the United States is New York City (NYC), and the island of Manhattan currently hosts the highest density of LEED and/or Energy Star certified buildings in the nation. This metropolitan city was attempting to improve the sustainability of its building stock to enhance the quality of life for residents and the city's overall economic status by focusing on improving environmental conditions throughout NYC via PlanNYC (The City of New York 2014). NYC contained the second largest number of LEED certified buildings of any metropolitan cities in the U.S. and the 4th highest number of Energy Star certified buildings. Of particular interest for this study, about 80 percent of the city's LEED certified buildings are located in the borough of Manhattan, as were 90 percent of the Energy Star certified buildings in NYC as of 2012. Figure 5.1 describes the trend for LEED or Energy Star certified buildings in NYC from 2006 through 2012; the data was provided by the websites, www.gbig.org and www.energystar.gov.

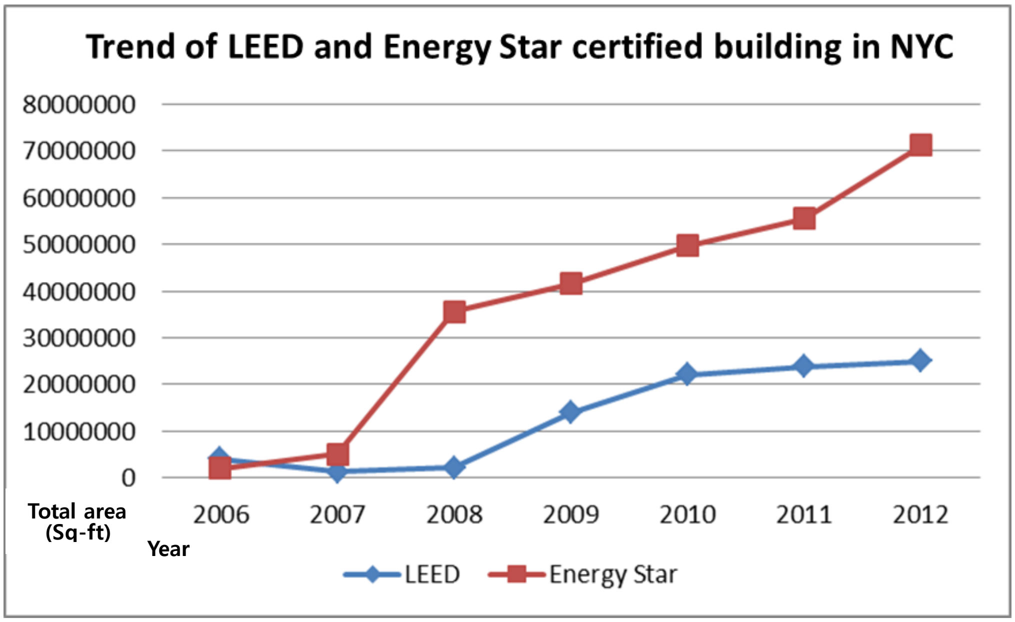

Figure 5.1. Trend of LEED and Energy Star certified buildings in NYC

Warren et al. (2013) indicated that only two metropolitan areas in the U.S., NYC and Washington, DC, featured among the markets with good or better investment prospects in 2011, although more U.S. cities have been added to this list since 2012. NYC is the only metropolitan area that has been consistently voted as a good or better investment prospect in the real estate market by survey respondents for every year from 2011 through 2014. Hence, the findings of this research are likely to be useful and directly applicable to other real estate markets with investment prospects that are good or better, including the cities already included in that group and other unranked metropolitan areas in the U.S.

Consequently, NYC was selected for this research to understand the spillover effects of LEED and/or Energy Star certified office building on buildings in the neighborhood with different proximities.

Choice of data sources and variables

This research utilized two major approaches: a geographical method and a statistical method. Thus, it required two different types of data as follows:

- Data set for the geographical analysis

The information on building characteristics and the geographic information for the LEED and/or Energy Star certified office buildings and the buildings in their neighborhood were provided by NYC's Department of City Planning (DCP), USGBC, and EPA to ensure the accuracy and keep the consistency of the information in the data sets. Although private information providers such as CoStar Group and Honest Building Solution also supplied this information, there was small discrepancy in the coverage of their information data sets. The geographical data sets for the Geographic Information System (GIS) provided by NYC's DCP are updated regularly to provide the latest information to all data users. The data set was supported for ArcGIS 10.1 and the most recent version, used here, was released in October 2013.

- Data set for the statistical analysis

The market value data set was collected from the website of NYC's DOF for the period from 2009 through 2015 and via a Freedom of Information Law (FOIL) request for 2007 to 2008, based on the fiscal year (FY) used for annual financial reports for all properties in NYC. The FY was based on the 12 month period from July 1 through June 30 the next year. The market value was converted to the unit market value based on information provided for the building area and the lot area, namely the property area, from the GIS data set, and the median unit market value was then calculated from the unit market values of all properties in each neighborhood area for each year from FY 2007 through FY 2013. Although the market value data sets ran from FY 2007 through FY

2013, the data sets for LEED and Energy Star certifications were available for the period from 2003 through 2013. Therefore, data were included from both data sets from FY 2007 up to and including FY 2013 based on data availability.

The variables used in this research consisted of one dependent variable and five independent variables for the statistical analysis, and Table 5.4 presented the relevant measurements and data sources.

Table 5.4. Study variables and the corresponding data sources

	Variable name	Measurement description	Data source	
LEED certification info	LEED certification level	LEED level (Certified:1/Silver:2/Gold:3/Platinum:4)	USGBC	Independent variable
	LEED certification coverage	Certification for a whole building or a part of building (Non:0/Partially:1/Fully:2)	USGBC	
	LEED certified year	Certified year (Non-certified year:0/Certified year:1)	USGBC	
Energy Star certification info	Energy Star certified year	Annual renewal (Non-certified year:0/Certified year:1)	EPA	
Market value	Unit market value of LEED and/or Energy Star certified office building (2007-2013)	Market value of property (in dollars) divided by the property area (in sq-ft).	NYC's DOF	
	Median unit market value of buildings in the neighborhood (2007-2013)	The median of the set of all property unit market values for properties in a neighborhood. Median value of unit market value (preventing the limitation of mean value theorem)	NYC's DOF	Dependent variable

Definition of the status of LEED certification from the change of LEED certification level and coverage due to the re-achievements of LEED certification

Energy Star certification is either achieved or not achieved by a building. Once achieved, if a building's stakeholders wish to maintain the certification, it must be renewed annually through a re-evaluation based on the results of building performance during the certified year. In contrast, LEED certification does not require this re-evaluation when renewing the LEED certification for another year. However, it is possible to re-achieve another, higher, LEED certification or extend the LEED certification coverage from part of a building to the whole building. In the screened population used for this study, 15 LEED certified office buildings achieved more than two LEED certifications by enhancing their initial LEED certification levels, extending their current LEED certification coverage from part of the building to the whole building, and/or adding another LEED certification for a specific part of an office building that had already achieved LEED certification for the whole building. Table 5.5 shows the list of office building that achieved more than two LEED certifications in Manhattan, NYC, during the study period.

Table 5.5. Defining the coverage and level of LEED certification for the multiple achieving LEED certified office buildings

No.	History of multiple LEED certification achievements (Coverage/Level)								Defining the coverage and level of LEED certified office building (Coverage/Level)
1	1st	Full/ Certified	2nd	Partial/ Gold	3rd	N/A	4th	N/A	Full/ Certified
2	1st	Full/ Certified	2nd	Full/ Silver	3rd	N/A	4th	N/A	Full/Silver
3	1st	Full/ Silver	2nd	Full/ Gold	3rd	N/A	4th	N/A	Full/Gold
4	1st	Full/ Gold	2nd	Partial/ Certified	3rd	N/A	4th	N/A	Full/Gold
5	1st	Partial/ Gold	2nd	Full/ Silver	3rd	N/A	4th	N/A	Full/Silver
6	1st	Full/ Certified	2nd	Full/ Gold	3rd	N/A	4th	N/A	Full/Gold
7	1st	Full/ Silver	2nd	Partial/ Silver	3rd	N/A	4th	N/A	Full/Silver
8	1st	Full/ Silver	2nd	Partial/ Gold	3rd	N/A	4th	N/A	Full/Silver
9	1st	Full/ Silver	2nd	Partial/ Gold	3rd	N/A	4th	N/A	Full/Silver
10	1st	Full/Gold	2nd	Full/Gold	3rd	N/A	4th	N/A	Full/Gold
11	1st	Partial/ Gold	2nd	Full/ Silver	3rd	N/A	4th	N/A	Full/Silver
12	1st	Full/ Silver	2nd	Partial/ Gold	3rd	N/A	4th	N/A	Full/Silver
13	1st	Full/ Silver	2nd	Partial/ Gold	3rd	N/A	4th	N/A	Full/Silver
14	1st	Full/ Gold	2nd	Partial/ Platinum	3rd	Partial/ Platinum	4th	N/A	Full/Gold
15	1st	Partial/ Silver	2nd	Full/ Gold	3rd	Partial/ Platinum	4th	Partial/ Platinum	Full/Gold

For the purposes of this study, the coverage and level of a LEED certified office building that achieved multiple LEED certifications with different coverages and higher LEED certification levels was defined based on the level of LEED certification coverage and the hierarchy of LEED certification level. LEED certification for a whole building took precedence over LEED certification for part of building, after which the higher level of LEED certification, which ranges from Certified through Platinum, was given priority to define the level of a LEED certified office building with more than two LEED certifications for the study period. For instance, the 14th LEED certified office building in Table 5.5 achieved one LEED certification for a whole office building with a Gold level as an initial LEED certification and two additional LEED certifications for particular parts of this office building with two Platinum levels. In this case, the LEED certified office building was defined as LEED certification for the whole building with a Gold level because LEED certification for a whole office building took priority over the additional LEED certifications for particular parts of the office building in spite of the higher levels of both additional LEED certifications. Table 5.5 shows the coverage and levels assigned to the 15 LEED certified office buildings which achieved multiple LEED certifications from 2007 through 2013 for this study.

Definition of the neighborhood areas and sub-neighborhood of the LEED and/or Energy Star certified office buildings

This research focused on the spillover effect of LEED and/or Energy Star certified office buildings on buildings in their neighborhoods by analyzing the correlation between a LEED and/or Energy Star certified office building and other buildings in its vicinity based on the unit market values of the buildings. Theoretically, a neighborhood is defined as a district or locality characterized by homogenous groups, and the neighborhood boundary usually coincides with a well-defined natural or man-made barrier or is based on a distinctive characteristic of the inhabitants. In this research, the neighborhood was defined by the standard measure of walkable distance in NYC due to the importance of this factor for local property value as external features in the existing environment, as discussed earlier. In addition, this study assumed that each sub-neighborhood had homogeneous external feature in its existing environment, with the only significant variation being the proximity to the LEED and/or Energy Star certified office building. The maximum walkable distance was taken to be a quarter of a mile (0.25 miles) for the purposes of this study as every building in Manhattan NYC is located within a 15 minute walk of a subway entrance, which is roughly the equivalent of 0.25 miles. The maximum neighborhood boundary was therefore taken to be the same as the maximum walkable distance, 0.25 miles, and the maximum neighborhood boundary was then divided into five sub-neighborhood areas by increments of 0.05 miles to measure the spillover effects of a LEED and/or Energy Star certified office building on the median unit market value of buildings in each sub-neighborhood based on their proximity to the LEED and/or Energy Star certified office building.

Previous studies have usually selected target areas based on their distance from a subject building by drawing several concentric rings at steadily increasing distances out from the central subject building (Retsinas and Belsky 2002; Haider and Miller 2007). However, Pollakowski and Wachter (1990) took an alternative approach, instead basing the measurements of the spillover effect on the distance from a subject building to a particular target boundary with drawing concentric doughnuts. Figure 5.2 illustrates the difference between the concept of concentric rings and that of concentric doughnuts.

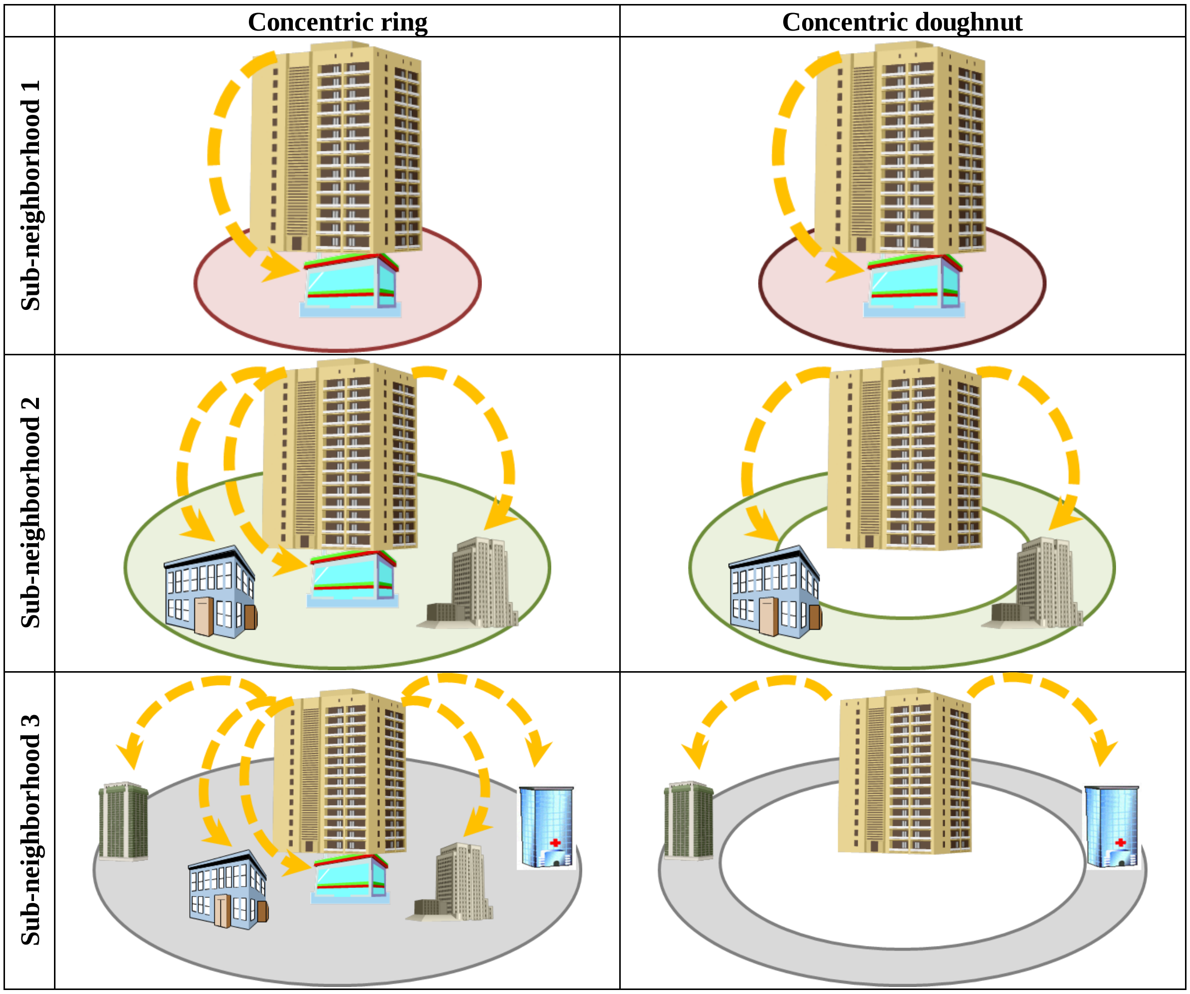

Figure 5.2. Difference between concentric ring-shaped sub-neighborhoods and concentric doughnut-shaped sub-neighborhoods

This alternative approach, focusing on each independent area without overlapping any buildings, provides a useful way to calculate the median values of buildings in urban areas that avoids problems due to overlapping housing values for the median housing values in each neighborhood. Hence, for this research the sub-neighborhood areas were selected by drawing five concentric doughnuts around each LEED and/or Energy Star certified office building to avoid the multiple counting of buildings in each sub-neighborhood and calculate the median unit market value of each sub-neighborhood. This ensured a tight focus on each specific sub-neighborhood surrounding every LEED and/or Energy Star certified office building rather than simply recording the distance from a

LEED and/or Energy Star certified office building and the neighborhood boundaries. Properties were counted in the zone where the majority of their footprint appeared. Therefore, this research was based on sub-neighborhood zones consisting of these five concentric doughnut-shaped sub-neighborhoods to calculate the median unit market value of buildings in the sub-neighborhood of each LEED and/or Energy Star certified office building rather than adopting simple neighborhood boundaries based on drawing five concentric rings with increasing radii around each LEED and/or Energy Star certified office building to represent the five sub-neighborhoods surrounding each LEED and/or Energy Star certified office building.

To decide which approach was most appropriate for this research, a subset of data was evaluated using both methods, with considerable agreement resulting. Therefore, the first method was selected since it was more convenient to consider only the buildings in each sub-neighborhood zone without repeated counting of unit market values of buildings in each sub-neighborhood for calculating the median unit market value of buildings in each sub-neighborhood of a LEED and/or Energy Star certified office building. Moreover, there was little difference between the median unit market values of concentric doughnut-shaped sub-neighborhoods and concentric ring-shaped sub-neighborhoods and the trend of both types of sub-neighborhoods was almost similar over time. For our analysis this study chose to utilize a mathematical approach that focused on the neighborhood areas and considered the buildings in the concentric doughnut shaped sub-neighborhoods for the calculation of median unit market values for all sub-neighborhoods. Figure 5.3 shows the difference in the median unit market values between the concentric doughnut-shaped sub-neighborhoods and the concentric ring-shaped sub-neighborhoods from 2007 through 2013, along with the associated trends for both types of sub-neighborhoods over time.

A particular building located on the boundary line between two sub-neighborhood zones for a LEED and/or Energy Star certified office building such as the boundary line between a sub-neighborhood 0.05 and a sub-neighborhood 0.1 was included in the data for both of the sub-neighborhoods. In these cases, the unit market value of this building was counted in both sub-neighborhood when calculating the median unit market value of buildings in the sub-neighborhoods because the study focused not on the individual unit market values for every building in the sub-neighborhood but the median unit market value of the buildings in each sub-neighborhood. A comparison of the effect of including buildings located on a sub-neighborhood boundary line in the count for one side or both on the median unit market value of buildings in each sub-neighborhood revealed the impact to be negligible. Table 5.6 and Figure 5.4 present the definition of sub-neighborhoods and the building distribution status for each sub-neighborhood used in this research.

Figure 5.3. Comparison of median unit market values between doughnut shaped sub-neighborhoods and circle shaped sub-neighborhoods over time

Some LEED and/or Energy Star certified office buildings were included in the sub-neighborhoods of other LEED and/or Energy Star certified office buildings as a neighboring building. The distribution of the LEED and/or Energy Star certified office buildings that also played a role as a neighboring building are presented in Figure 5.3. Although a few office buildings which achieved LEED and/or Energy Star certification in the sub-neighborhoods were included in the neighboring buildings for some sub-neighborhoods, it was assumed that the median unit market value of buildings in the sub-neighborhoods for each LEED and/or Energy Star certified office building would not have a significant impact on the results given the relatively limited number of office buildings that have achieved LEED and/or Energy Star certification. Also, as mentioned above, this study focused on not the individual unit market values of each neighboring building but rather the median unit market value of the buildings in each sub-neighborhood. The median unit market value was by its nature insensitive to changes in the unit market value of individual buildings and to outliers (Drennan 2009). Therefore, the median unit market value of buildings for each sub-neighborhood included the unit market values of LEED and/or Energy Star certified office buildings that fell within the sub-neighborhoods of other LEED and/or Energy Star certified office buildings when the median market value of buildings in each sub-neighborhood were calculated.

Table 5.6 Classification zones for sub-neighborhoods of LEED and/or Energy Star certified office buildings based on proximity to a LEED and/or Energy Star certified office building

Sub-neighborhood classification	Boundaries of sub-neighborhood areas
Sub-neighborhood 0.05	0 mile – 0.05 miles
Sub-neighborhood 0.1	0.05 miles – 0.1 mile
Sub-neighborhood 0.15	0.1 mile – 0.15 miles
Sub-neighborhood 0.2	0.15 miles – 0.2 miles
Sub-neighborhood 0.25	0.2 miles – 0.25 miles

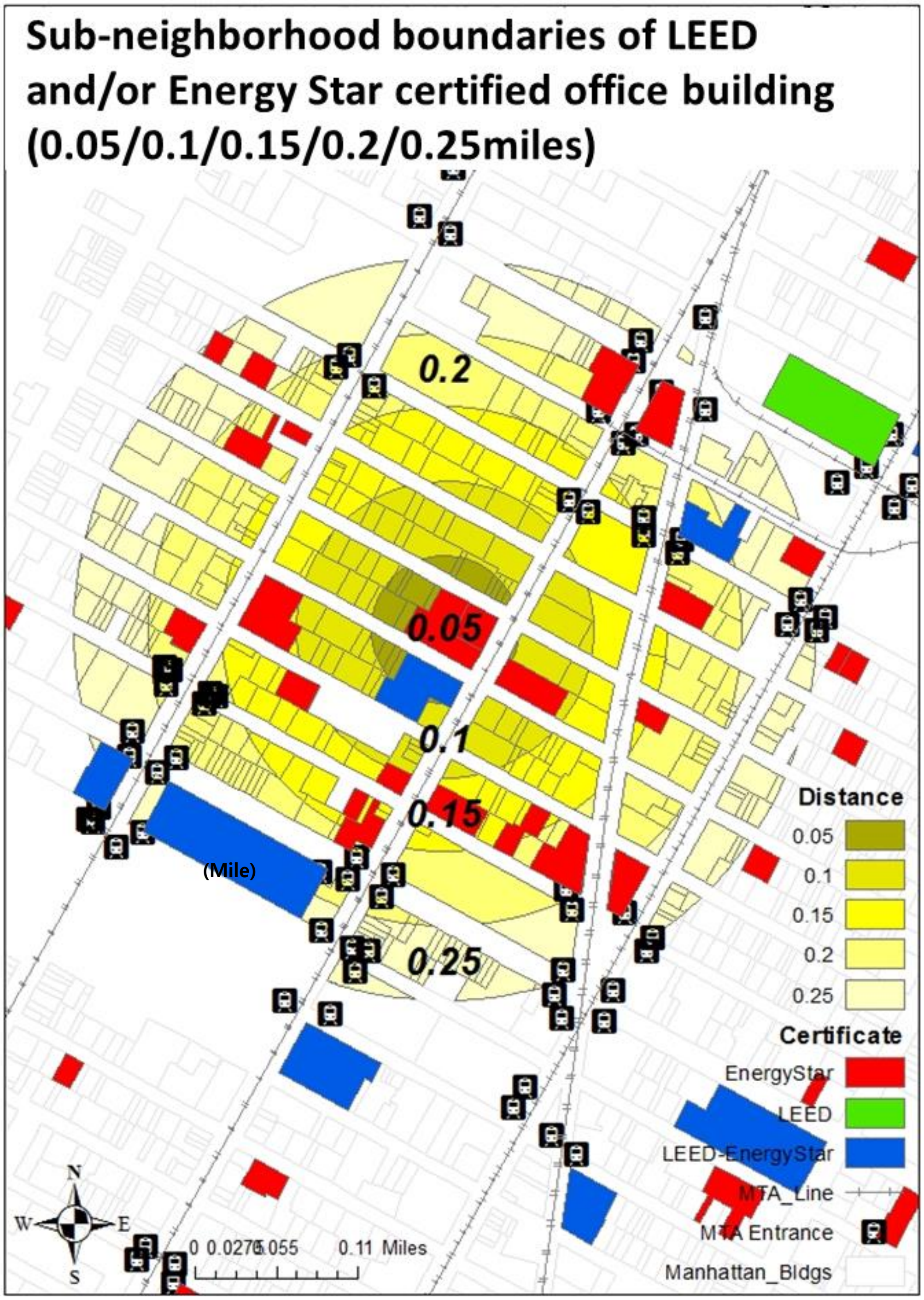

Figure 5.4. Example of the five doughnut-sub-neighborhoods around an Energy Star certified office building, with LEED and/or Energy Star certified office buildings included in the sub-neighborhoods as neighboring buildings

The high density of LEED and/or Energy Star certified office buildings in the midtown and downtown parts of Manhattan and the relatively close distances between LEED and/or Energy Star certified office buildings generated numerous overlapping areas between the sub-neighborhoods of LEED and/or Energy Star certified office buildings. Almost the entire Midtown region is included in the neighborhood of one or more LEED and/or Energy Star certified office buildings, as is the majority of the southwest section of Manhattan. The example of overlapping areas of sub-neighborhoods of two Energy Star certified office buildings shown in Figure 5.5 reveals ten areas of overlap in just this single example, with each overlapping area representing two different sub-neighborhood radii, one from each of the Energy Star certified office buildings. It seems likely that building located in these overlapping areas will be affected by two different economic impacts from the Energy Star certified office buildings on each side. As the focus of this study was to investigate the economic impact of LEED and/or Energy Star certified office buildings on their neighborhood, which was divided into five sub-neighborhoods based on the proximity to the certified building and the median unit market value of the buildings in each of the five sub-neighborhoods determined individually, the economic impacts of the LEED and/or Energy Star certified office buildings were assumed to be independent of each other and the overlapping areas of sub-neighborhoods of LEED and/or Energy Star certified office buildings was identified as a limitation of the statistical research model used.

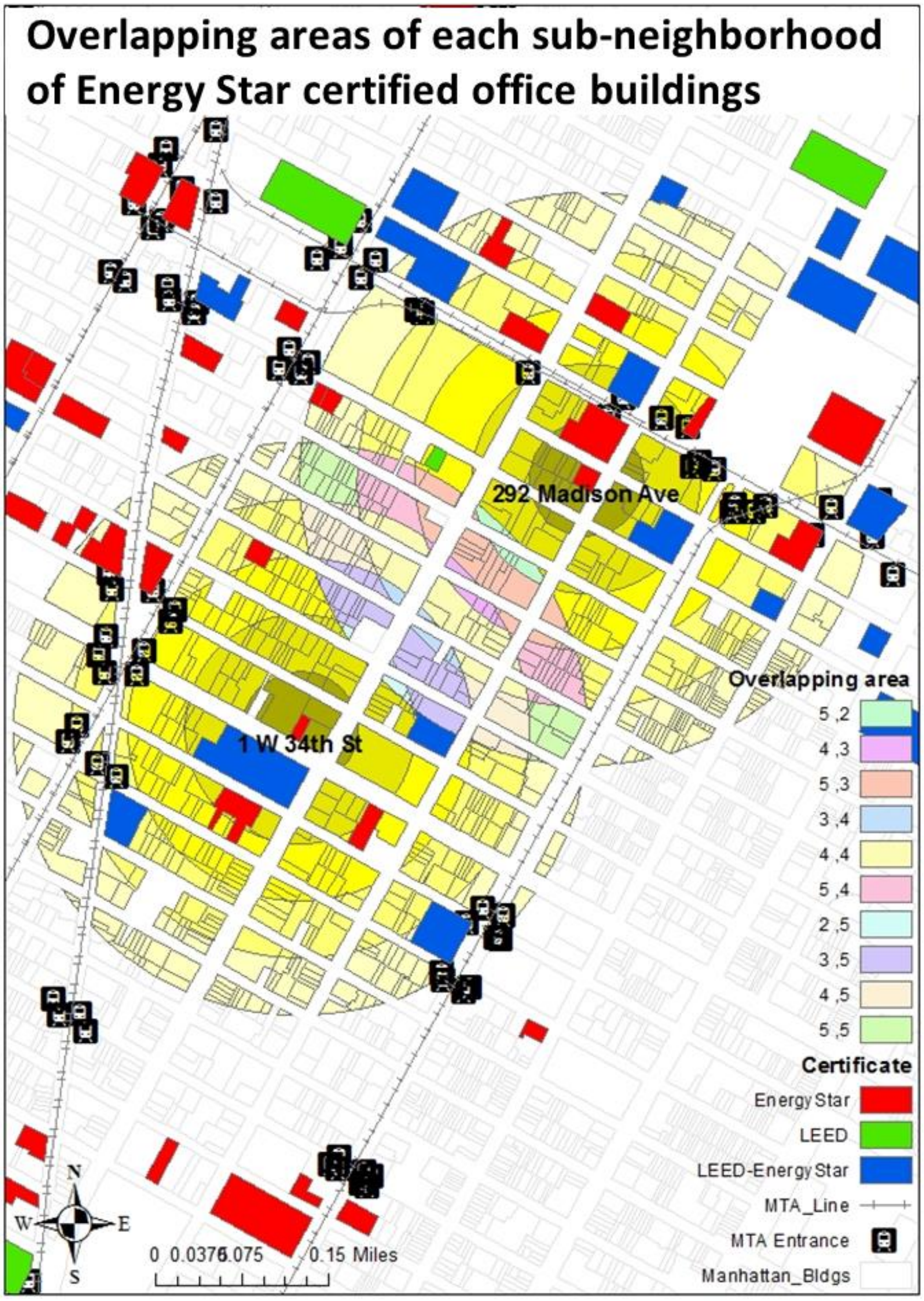

Figure 5.5. Overlapping sub-neighborhoods of Energy Star certified office buildings

Note. The significance of the numbers used to label the overlapping areas is as follows: 1: Sub-neighborhood 0.05, 2: Sub-neighborhood 0.1, 3: Sub-neighborhood 0.15, 4: Sub-neighborhood 0.2, 5: Sub-neighborhood 0.25 and the order of numbers. The certified buildings at the center of each pattern are located at 1 W 34th St. and 292 Madison Ave.

Analytical approach

This research applied two major approaches, geographical and statistical, to analyze the spillover effects of LEED and/or Energy Star certified office buildings on buildings in their neighborhood. The geographical characteristics of the LEED and/or Energy Star certified office buildings were displayed on a map that incorporated the information gathered on the target buildings and their neighborhoods, including the market values provided by NYC′s DOF and information on both types of certification provided by USGBC and EPA using the GIS tool, ArcGIS 10.1. This program utilized the fundamental data set to facilitate the analysis of correlations between LEED and/or Energy Star certified office buildings and their neighborhood areas, as well as the strength and direction of spillover effects for each of the different proximity groups for each LEED and/or Energy Star certified office building. The statistical method applied here utilized the R-Project 3.0.1. More detailed descriptions and the processes involved in each approach were as follows:

- Geographical method

  The geographical method focused on establishing the spatial characteristics of the LEED and/or Energy Star certified office buildings and their sub-neighborhoods and enhancing the accuracy of the buildings' geographical locations because the accuracy of this information is fundamental for this research. ArcGIS 10.1 was therefore used to establish the precise spatial distribution of the LEED and/or Energy Star certified office buildings in Manhattan NYC and the five sub-neighborhoods surrounding each certified office building were identified by the measurement function known as 'Multiple Ring Buffer (Analysis)'. The specific tasks for the geographical method were as follows:

  - Develop a map that incorporates the information gathered for the LEED and/or Energy Star certified office buildings and other characteristics of the certified buildings.

  - Determine the distribution of LEED and/or Energy Star certified office buildings and assign each of their neighboring buildings to one of the incremental radii for neighborhood (0-0.05miles, 0.05-0.1miles, 0.1-0.15miles, 0.15-0.2miles, and 0.2-0.25miles).

- Integrate the data on LEED or Energy Star certification and the market value data on all properties in NYC.
- Construct a fundamental data set for the statistical treatment using the statistical computing program R-Project, and then integrate the all data sets by matching each building′s Borough-Block-Lot (BBL) designation.
- Export the integrated data set as a CSV file (whose format is supported) to R-Project for the subsequent analysis of the data set.

• Statistical method

Two different statistical methods were utilized in this study: descriptive analysis and regression analysis. The statistical methods were used to interpret the statistical results of the descriptive and regression analyses and to establish the numerical models using "R-Project 3.0.2". The significant features of LEED certification, the achievement of LEED and/or Energy Star certification, and the unit market value of the LEED and/or Energy Star certified office building from 2007 through 2013 all played a role as independent variables and the median unit market value of the buildings in each sub-neighborhood of the central LEED and/or Energy Star certified office building was designated as a dependent variable in this research. The information on the LEED and/or Energy Star certified office building therefore needed to be transformed from the non-numerical data format, syntax, into numerical data before performing the statistical regression analysis for items such as the LEED certification level, the LEED certification coverage of the office building, and the achievement of LEED and/or Energy Star certification. For this statistical method, the unit market value of a LEED and/or Energy Star certified office building included all changes in the unit market value of that building and the decrease or increase of unit market value after achieving LEED and/or Energy Star certification, throughout the period from 2007 through 2013 to ensure the accurate estimation of the economic impact of the LEED and/or Energy Star certified office building on the median unit market value of buildings in the sub-neighborhoods defined for the study. In addition to the unit market values of the LEED and/or Energy Star certified office buildings, the significant features of their LEED and/or Energy Star certification were considered as an independent variable in order to identify any correlations between these certifications and the dependent variable, the median unit market value of the buildings in each of the sub-neighborhoods. The results of the statistical method were therefore expected to identify the correlation between the independent variables and the dependent variable. The detailed tasks involved were as shown below.

- Analyze the data set exported from the geographical step, and then design an appropriate analysis model based on the hedonic price model and the linear mixed effect model.

- Identify the coefficients by simulating the data set using R-Project to determine the values of the coefficients, and then complete the equation for the linear mixed effect model based on the hedonic price model

- Interpret the direction and the number of coefficients in the equation for the linear mixed effect model to reveal the spillover effects of LEED and/or Energy Star certification on buildings in the neighborhood area based on their proximities to the LEED and/or Energy Star certified office building.

- Validate the numerical models produced by the statistical methods using Log-likelihood ratio statistics, which indicate the fitness of numerical models by comparing them with the null model.

Findings

The results of this research were developed by combining a geographical approach using ArcGIS 10.1 and a statistical approach using R-Project 3.0.2. A geographical survey of the locations of LEED and/or Energy Star certified office buildings in Manhattan, NYC, provided the basis for the determination of five different proximity zones based on the distance from each certified building, in increments of 0.05 miles out to the 0.25 mile "walkable distance" neighborhood boundary, and the allocation of specific buildings in each neighborhood to each sub-neighborhood. A statistical approach was then applied to examine the spillover effect of LEED and/or Energy Star certified office buildings on median unit market values in each sub-neighborhood and analyzing the correlation with the numerical results based on the outcomes from the geographical approach. The findings of this study presented below resulted from two different analyses: a geographical analysis and statistical analyses.

Geographical approach

The geographical approach played a fundamental role in this research as it was used to integrate the numerical data and select the sample group. In addition to determining the distribution of LEED and/or Energy Star certified office buildings and those of buildings in their neighborhoods in Manhattan, NYC, a geographical approach was also used to distinguish individual buildings within each different neighborhood zone. The market value data sets were added to the physical building information by matching each number of Borough-Block-Lot (BBL) of every building. The numbers of LEED and/or Energy Star certified office buildings in this research are shown in Table 5.6. As the data shows, most of the certified office buildings in Manhattan preferred to achieve Energy Star certification even when an office building was already LEED certified. There were only 14 office buildings with just LEED certification identified in this research, just 9.4% of all the certified office buildings in this study area. Table 5.7 presents the number of LEED and/or Energy Star certified office building in this study.

Table 5.7. Number of LEED and/or Energy Star certified office building in the sample of this research

LEED certification only	Energy Star certification only	LEED & Energy Star certifications	Total
14	89	46	149
9.4%	59.7%	30.9%	100%

An overview of the distribution of LEED and/or Energy Star certified office buildings and their neighborhoods, which include the five different sub-neighborhood boundaries from 0.05 miles to 0.25 miles, in Manhattan are shown in Figure 5.6. Figures 5.7 to 5.9 show the distribution of these buildings and their neighborhoods in detail for the three main regions of Manhattan: Uptown, Midtown and Downtown.

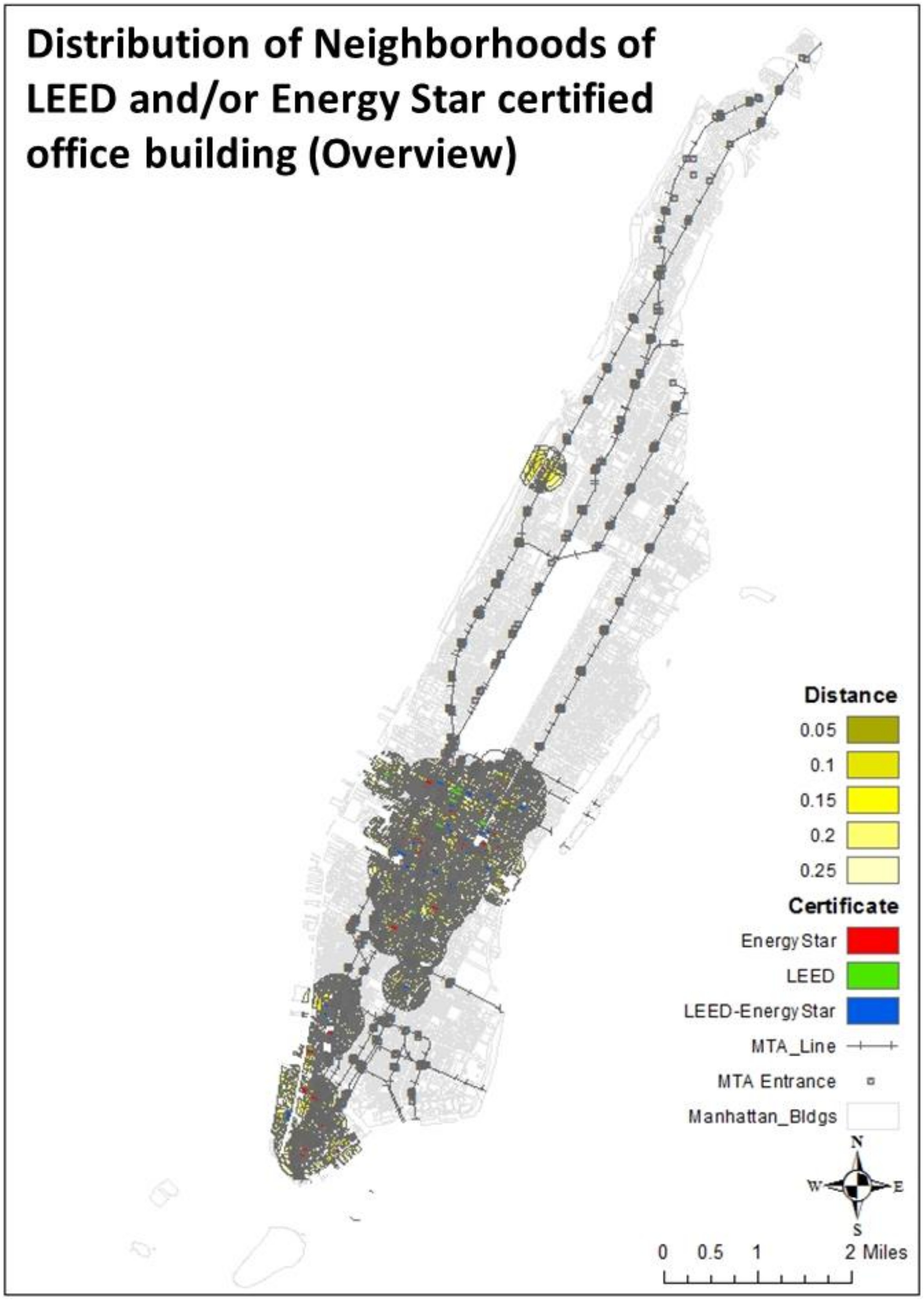

Figure 5.6. Distribution of the neighborhoods of LEED and/or Energy Star certified office buildings in Manhattan NYC

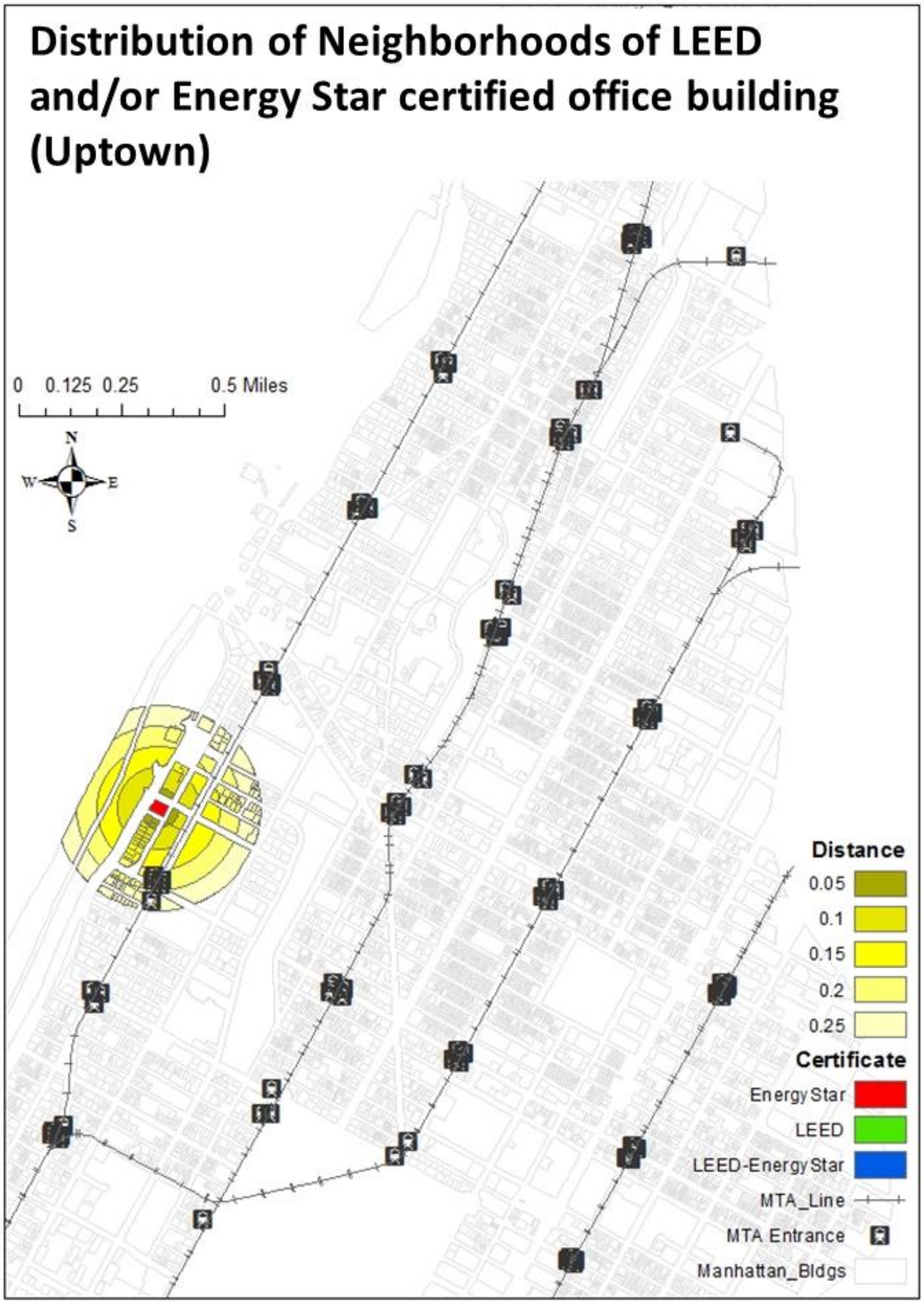

Figure 5.7. Neighborhoods of LEED and/or Energy Star certified office buildings in Uptown Manhattan

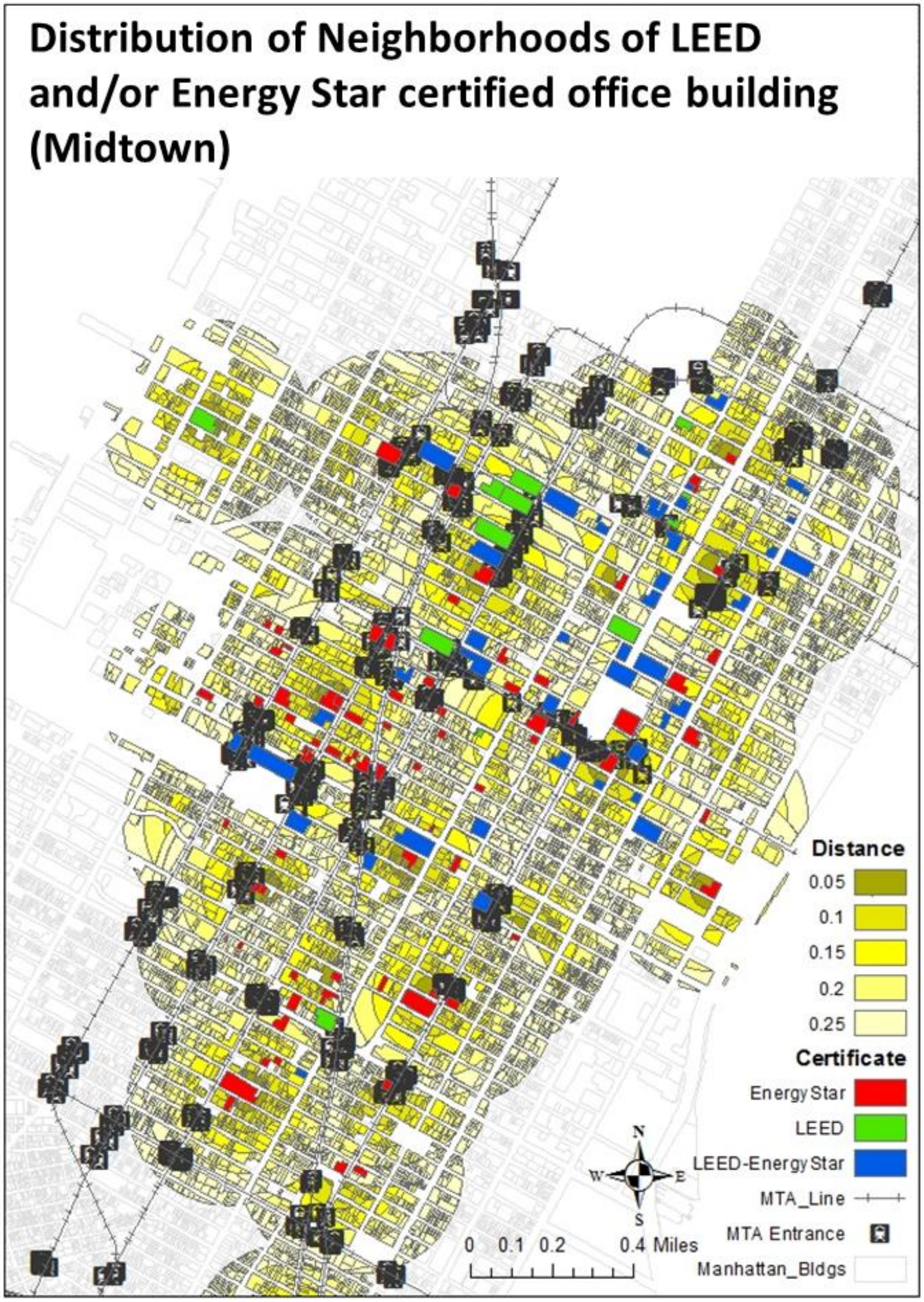

Figure 5.8. Neighborhoods of LEED and/or Energy Star certified office buildings in Midtown Manhattan

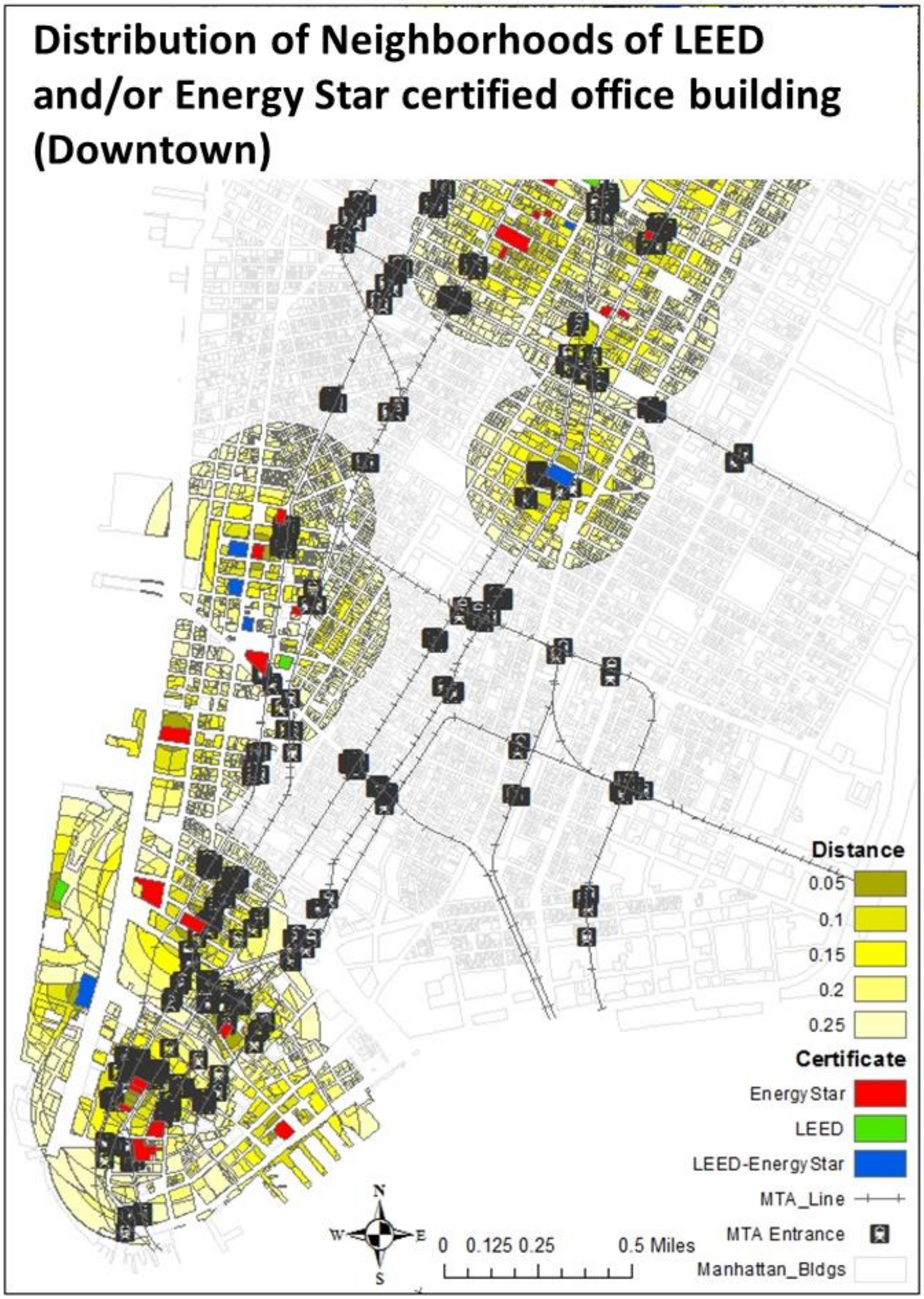

Figure 5.9. **Neighborhoods of LEED and/or Energy Star certified office buildings in Downtown Manhattan**

The number of office buildings in Manhattan that fall within the designated neighborhood zones of LEED and/or Energy Star certified office buildings and were thus used to calculate the median unit market value of the buildings in each sub-neighborhood was 77,530. This number exceeds the actual total number of buildings included in the study because the same buildings could be included in the neighborhoods of more than one LEED and/or Energy Star certified office building as a neighboring building. Furthermore, in some cases a LEED and/or Energy Star certified office building could also count as a building in one of the sub-neighborhoods of another certified building. The specific number of buildings within each neighborhood zone boundary for each certification type of office building is shown in Table 5.8.

Table 5.8. Specific number of buildings considered to be in each sub-neighborhood

Sub-neighborhood	LEED certification only	Energy Star certification only	LEED & Energy Star certifications
Sub-neighborhood 0.05	164	1817	769
Sub-neighborhood 0.1	592	5732	2476
Sub-neighborhood 0.15	1074	9384	4351
Sub-neighborhood 0.2	1730	13185	6965
Sub-neighborhood 0.25	2584	17568	9139
Total	6144	47686	23700

It was also possible to determine the proximity to a subway entrance of each building in all sub-neighborhoods using these figures. Almost all the buildings in each sub-neighborhood have convenient access to the closest subway entrance, as the greatest sub-neighborhood boundary was set by the “walkable distance”, 0.25 miles. All the sub-neighborhoods of LEED and/or Energy Star certified office buildings included more than one subway entrance within all five of the sub-neighborhood boundaries. However, there were several sub-neighborhoods of two of the LEED only certified office buildings and one of the Energy Star only certified office buildings that did not include any subway entrance within their sub-neighborhood boundaries, as shown in Figures 5.7 , 5.8, and 5.9.

Two methods were utilized to measure the greatest distance to a subway station: the recommended travel mode function for a pedestrian using Google maps and a calculation based on the geographic latitude and longitude of the two points. This study took the greatest straight-line distance between a building in each of the sub-neighborhoods and the closest subway entrance using the calculation method based on geographic latitude and longitude. The calculation results indicated that the distance between 166 W 46th St. and its closest MTA station, at 42nd St.-Port Authority Bus Terminal (Figure 5.7), was the furthest of any in the study. Based on the measurement method for the greatest distance in this study, however, it was reasonable to assume that a 0.58 mile-straight-line distance was considered a walkable distance in Manhattan, NYC, by NYC's Metropolitan Transportation Authority (NYC MTA), who stated that a 15 minute walk was an acceptable walkable distance. Therefore, all the buildings located within the sub-neighborhood boundaries were treated as being located within a walkable distance to the closest subway entrance. Moreover, this external condition in the existing environment could provide a homogenous economic situation in terms of the market value of the buildings in the sub-neighborhoods because all provided an equivalently convenient accessibility to the metropolitan subway transportation system and thus conveyed similar satisfaction to subway transit commuters traveling to all the buildings located in the sub-neighborhood of a LEED and/or Energy Star certified office building. Figures 5.10, 5.11, and 5.12 presented both measurement methods of distance, pedestrian walk route distance and straight-line distance, to the closest subway entrance from the furthermost building in the sub-neighborhoods of three certified office buildings.

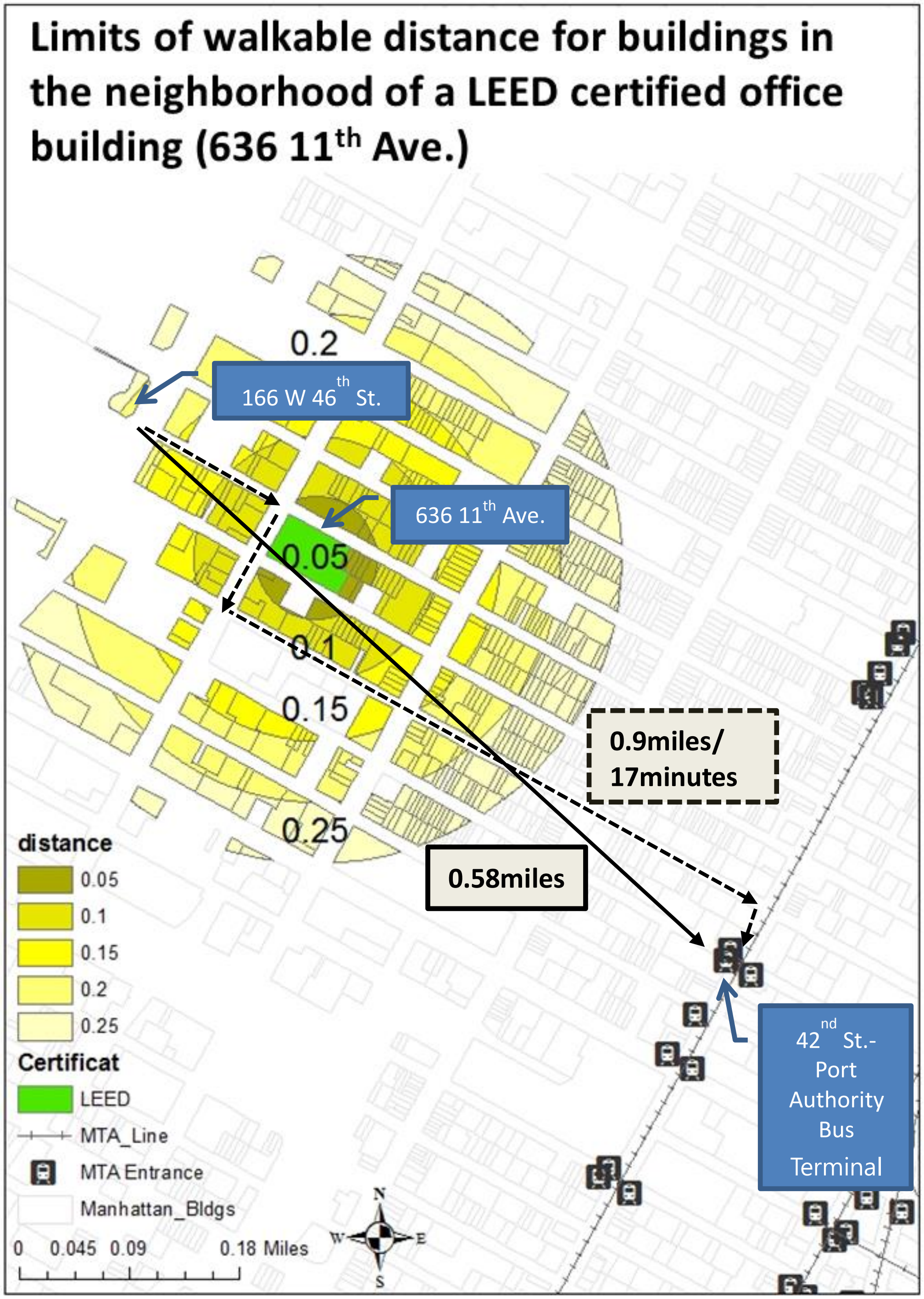

Figure 5.10. Walking distance to the nearest subway station from 166 W 46th St.

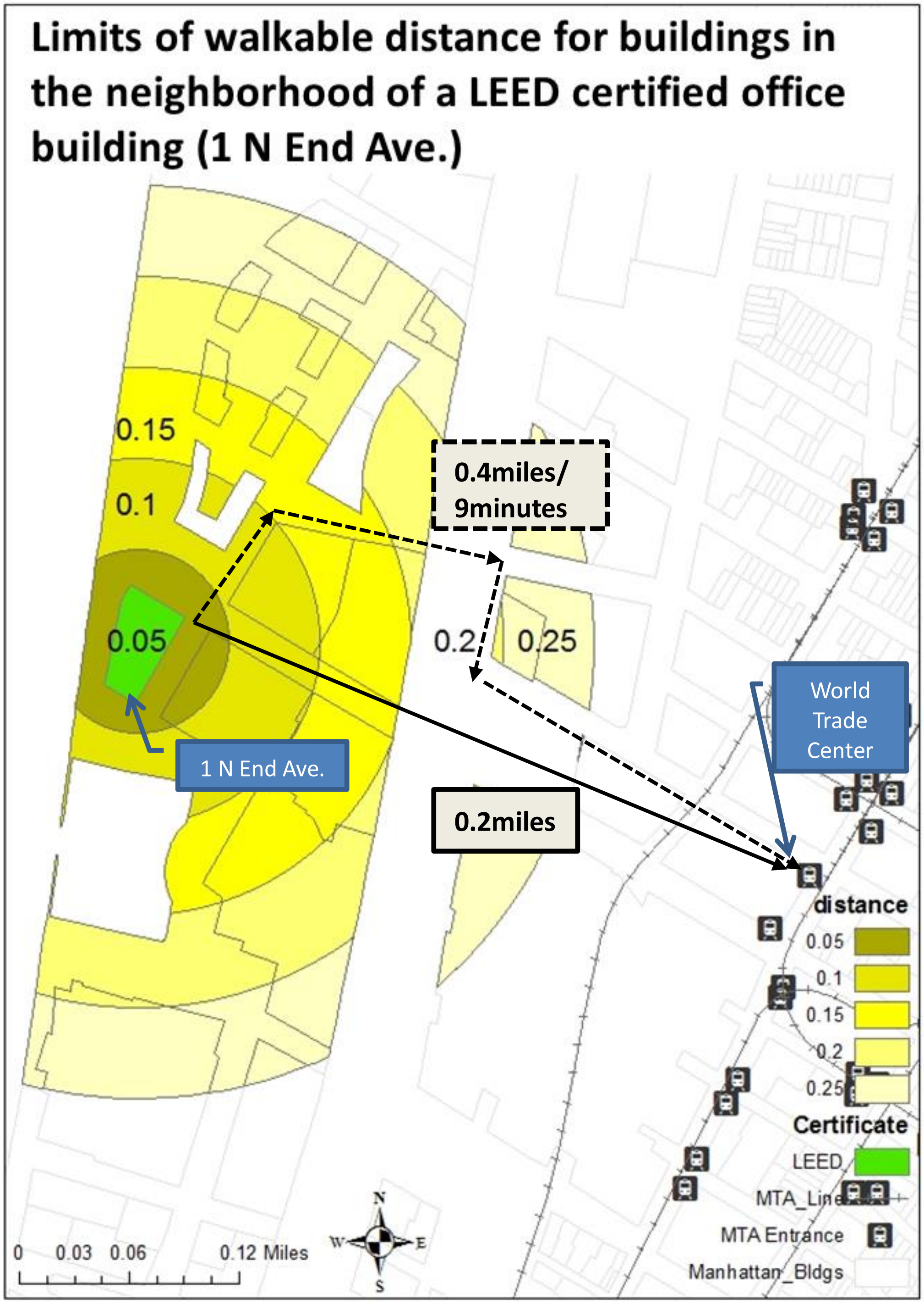

Figure 5.11. Walking distance to the nearest subway station from 1 N End Ave.

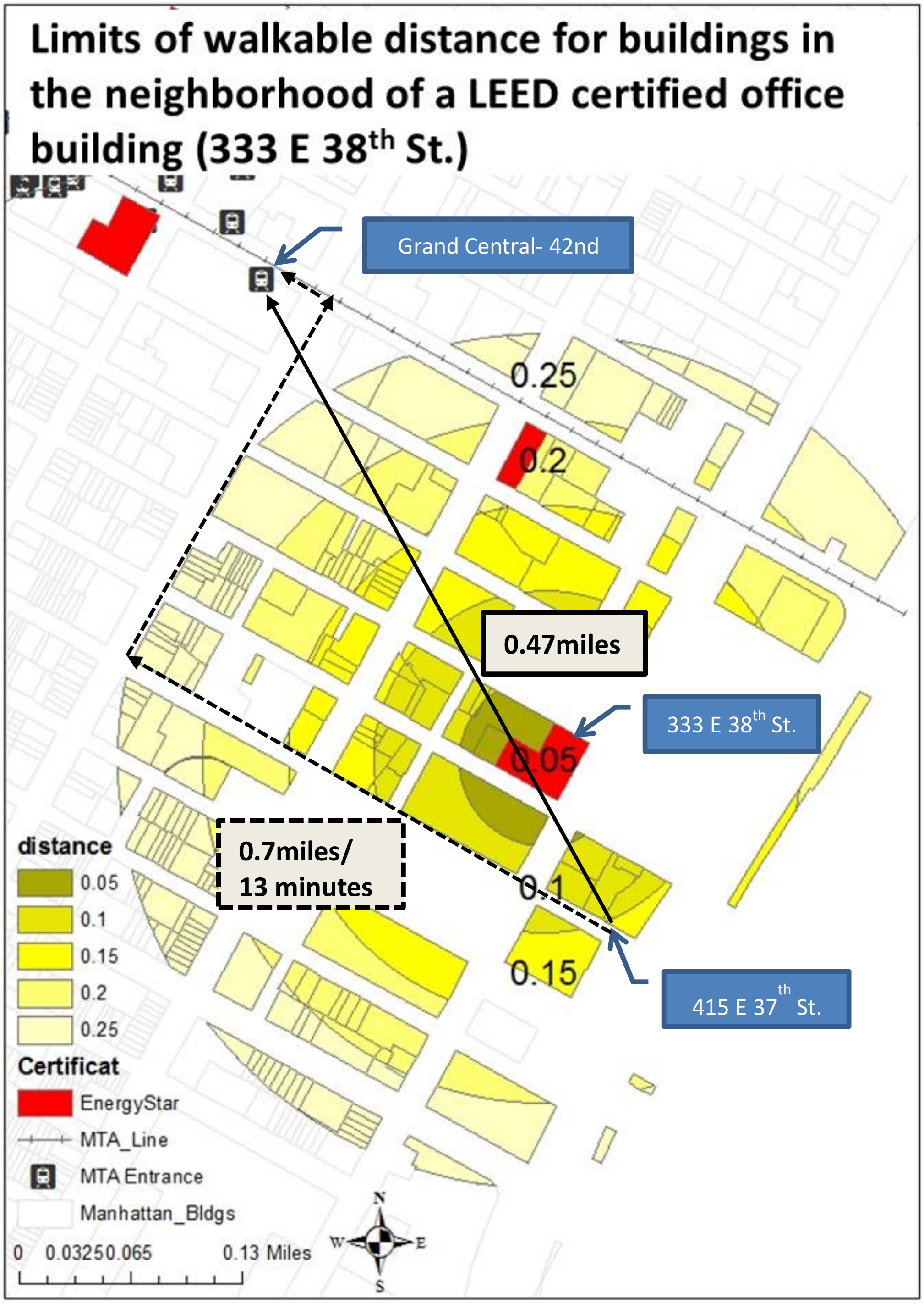

Figure 5.12. Walking distance to the nearest subway station from 333 E 38th St.

In addition, the distributions of buildings in all sub-neighborhoods of each type of certified office building are presented in Figures 5.13 to 5.22.

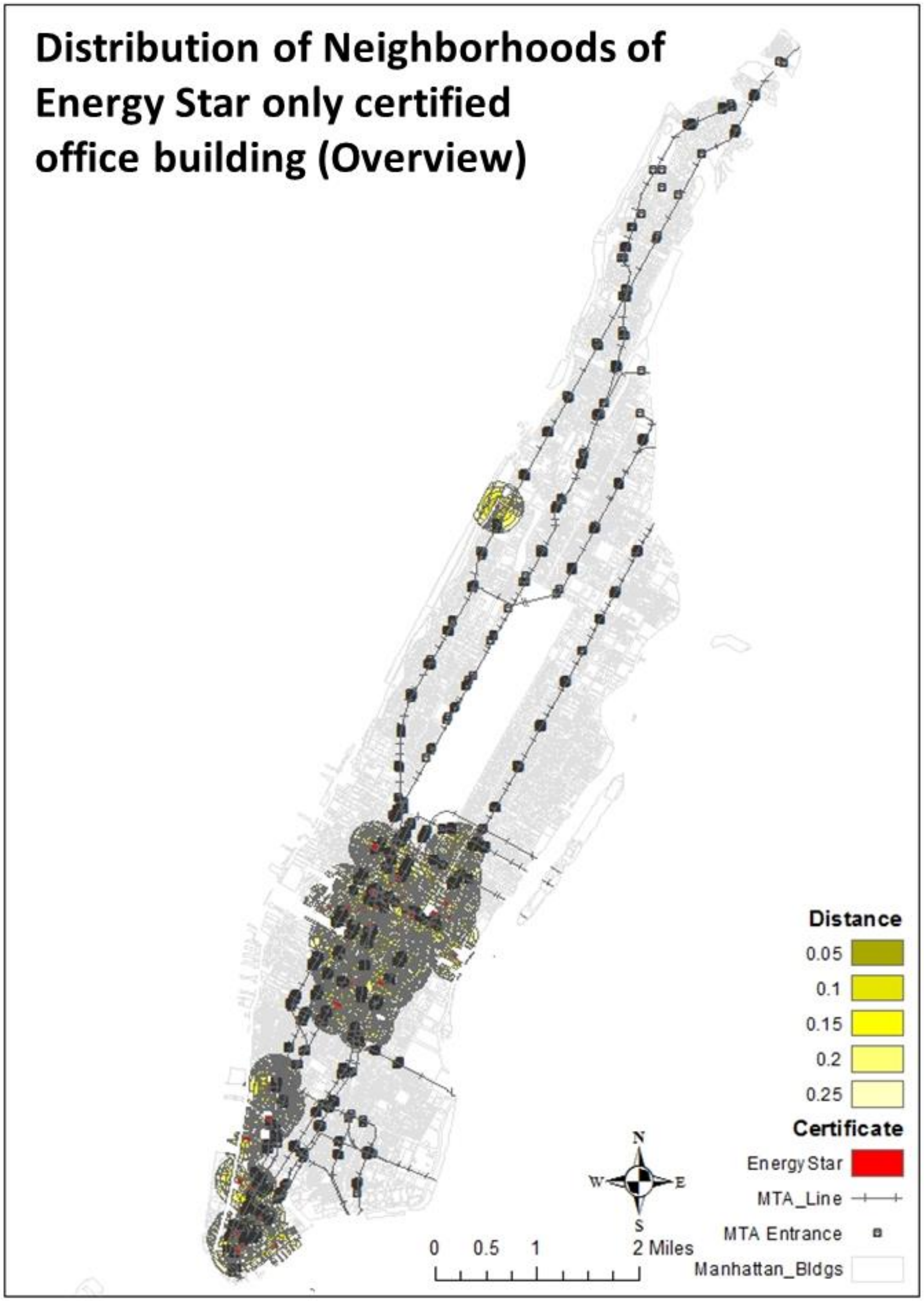

Figure 5.13. Distribution of the neighborhoods of Energy Star only certified office buildings in Manhattan NYC (Overview)

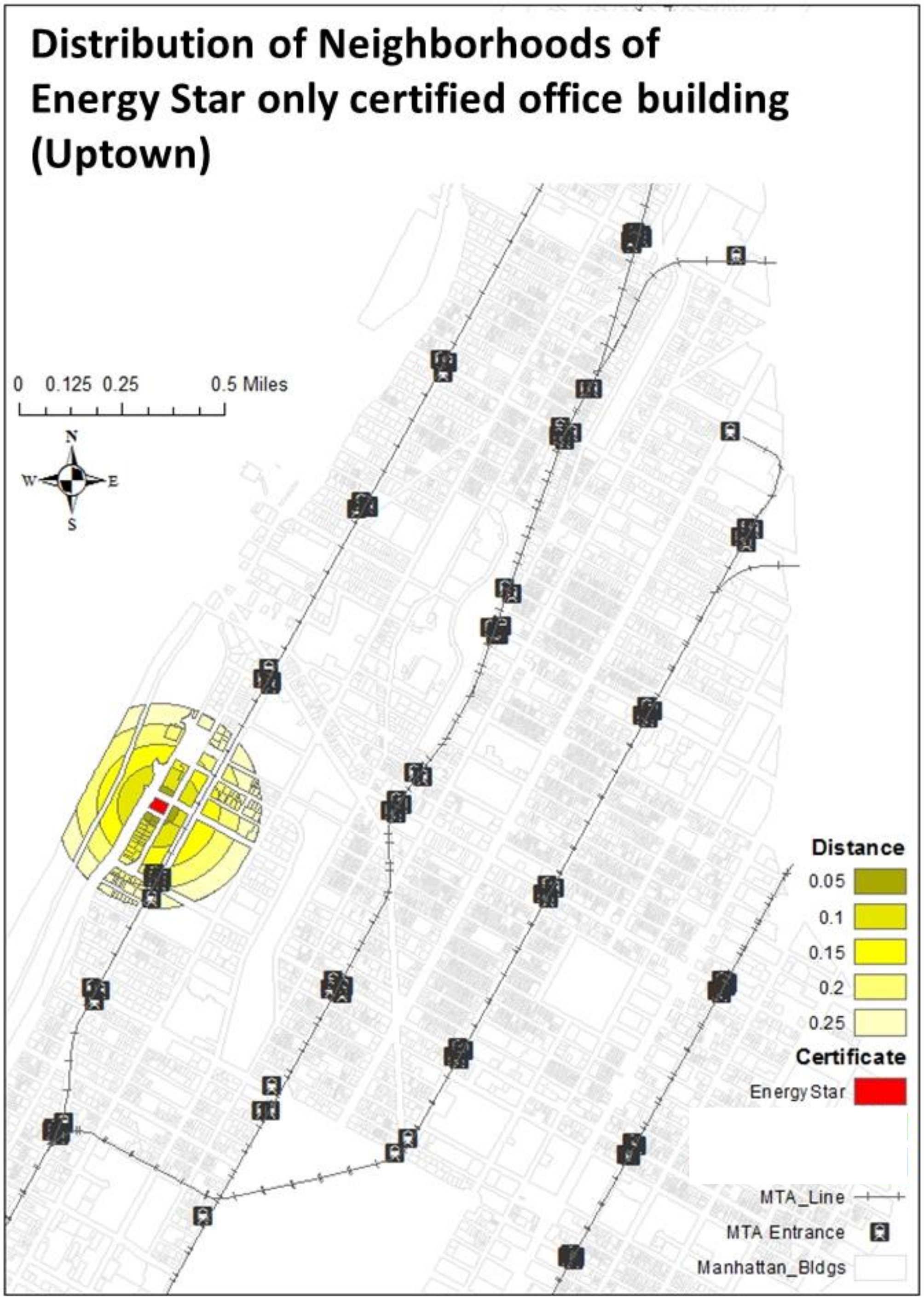

Figure 5.14. Distribution of neighborhoods of Energy Star only certified office buildings in Uptown Manhattan

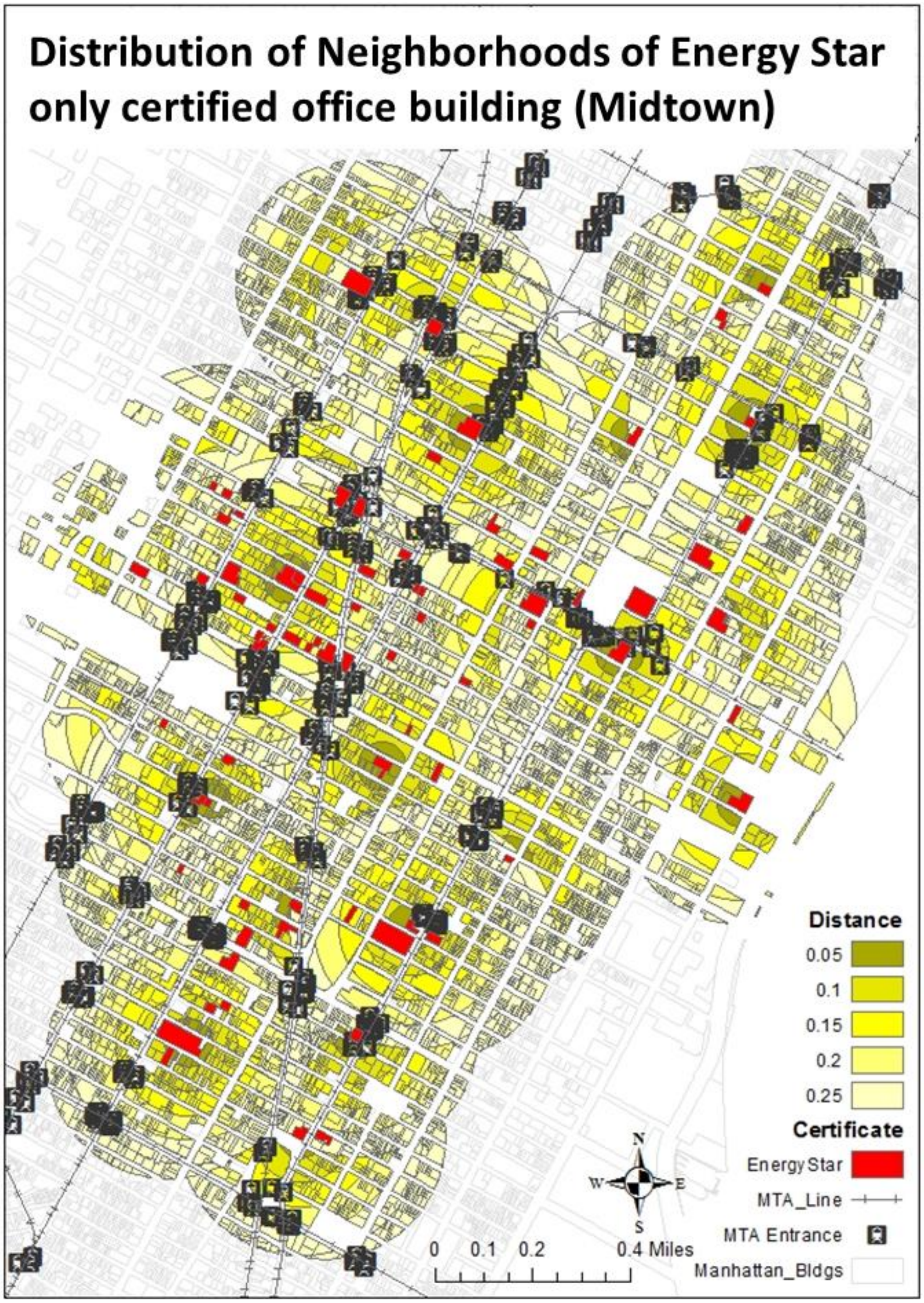

Figure 5.15. Distribution of neighborhoods of Energy Star only certified office buildings in Midtown Manhattan

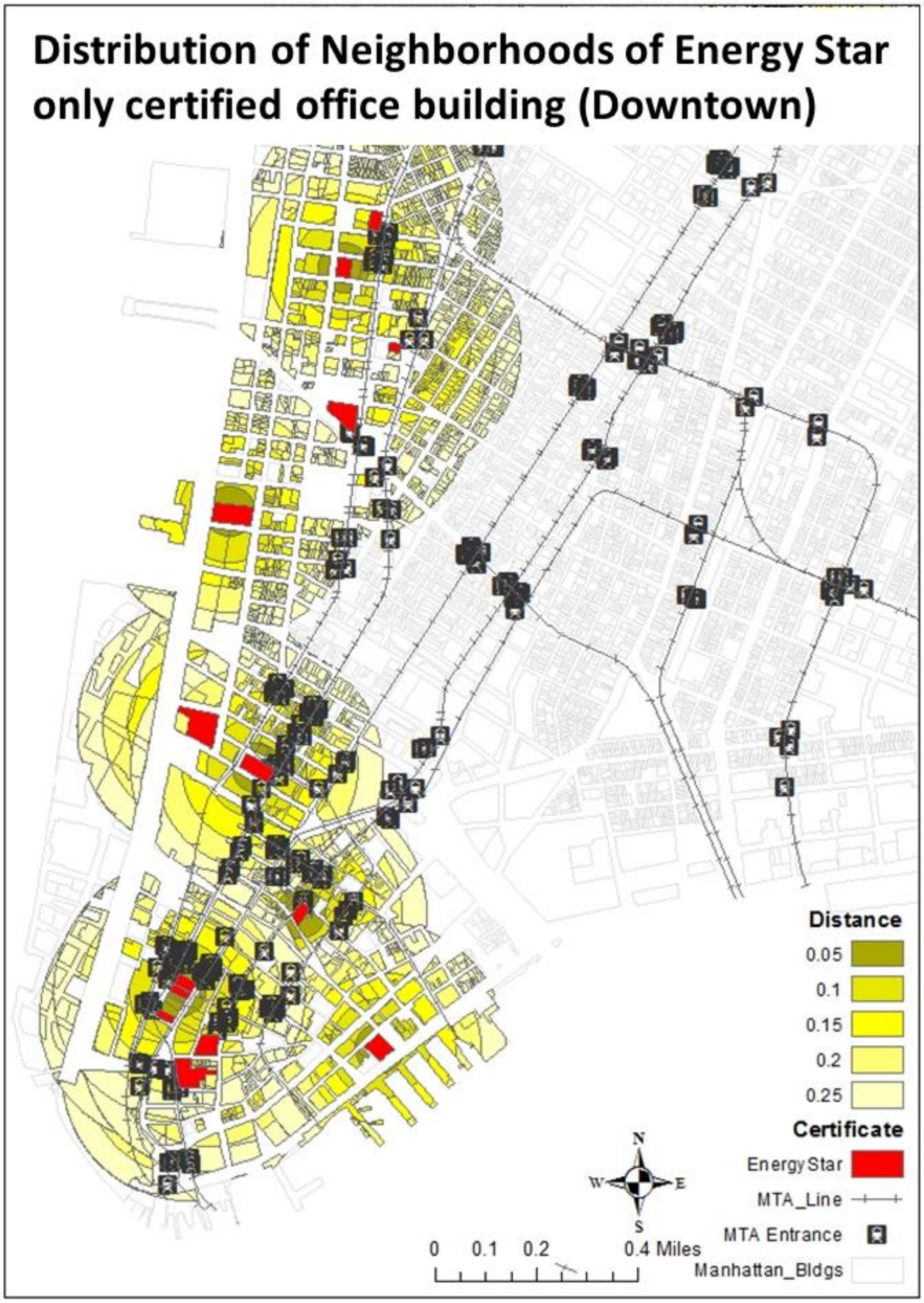

Figure 5.16. Distribution of neighborhoods of Energy Star only certified office buildings in Downtown Manhattan

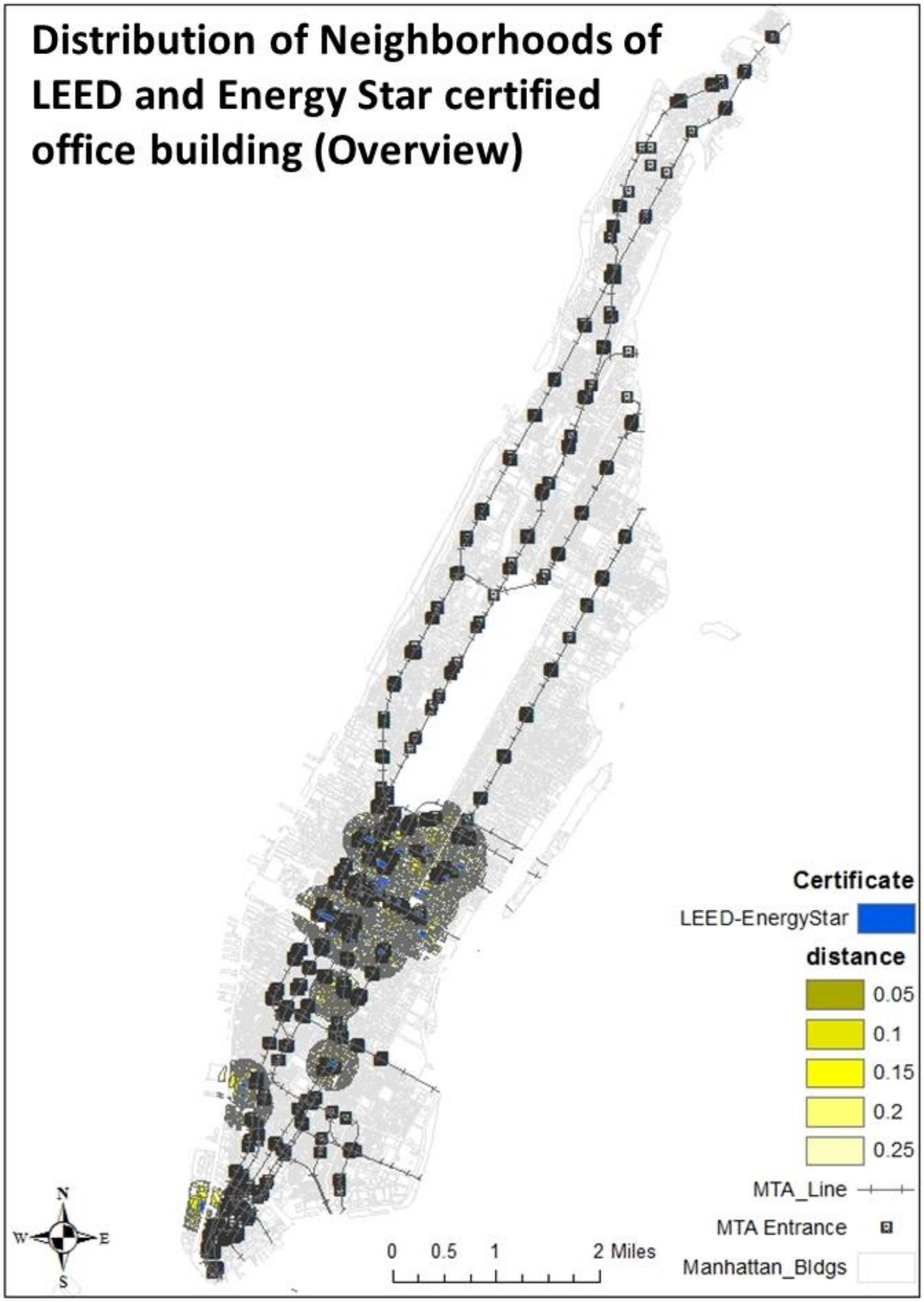

Figure 5.17. Distribution of neighborhoods of LEED and Energy Star certified office buildings in Manhattan NYC (Overview)

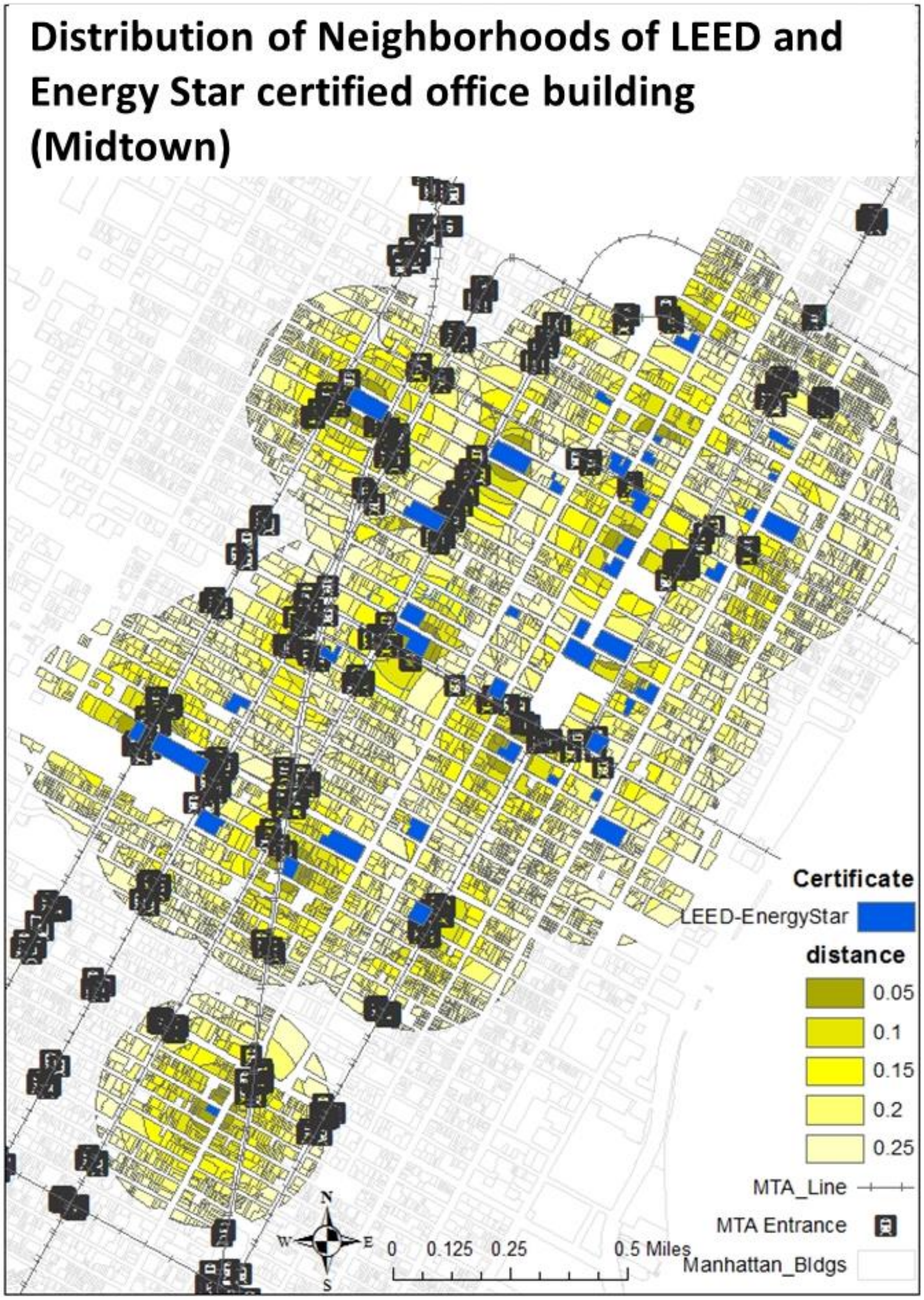

Figure 5.18. Distribution of neighborhoods of LEED and Energy Star certified office buildings in Midtown Manhattan

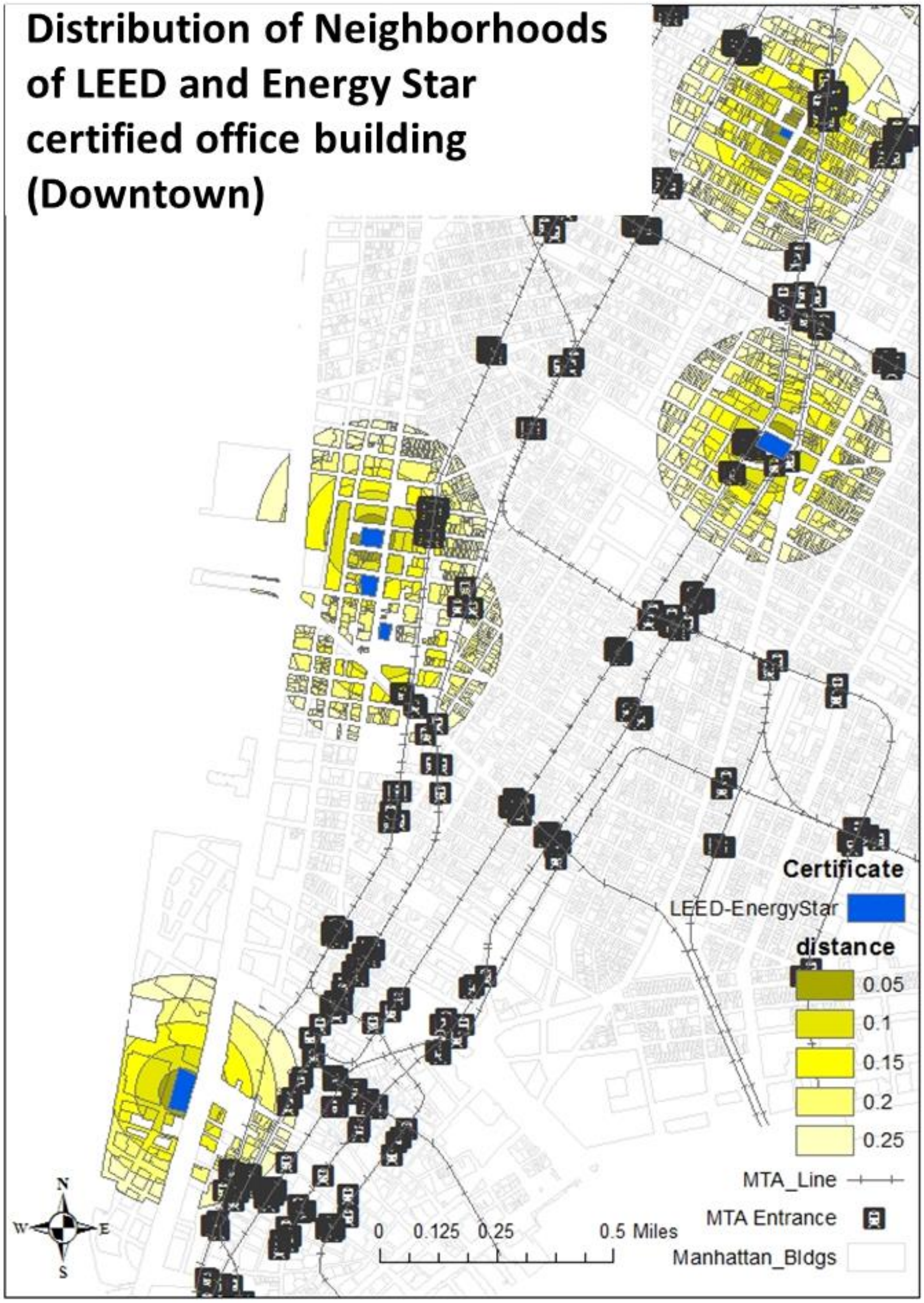

Figure 5.19. Distribution of neighborhoods of LEED and Energy Star certified office buildings in Downtown Manhattan

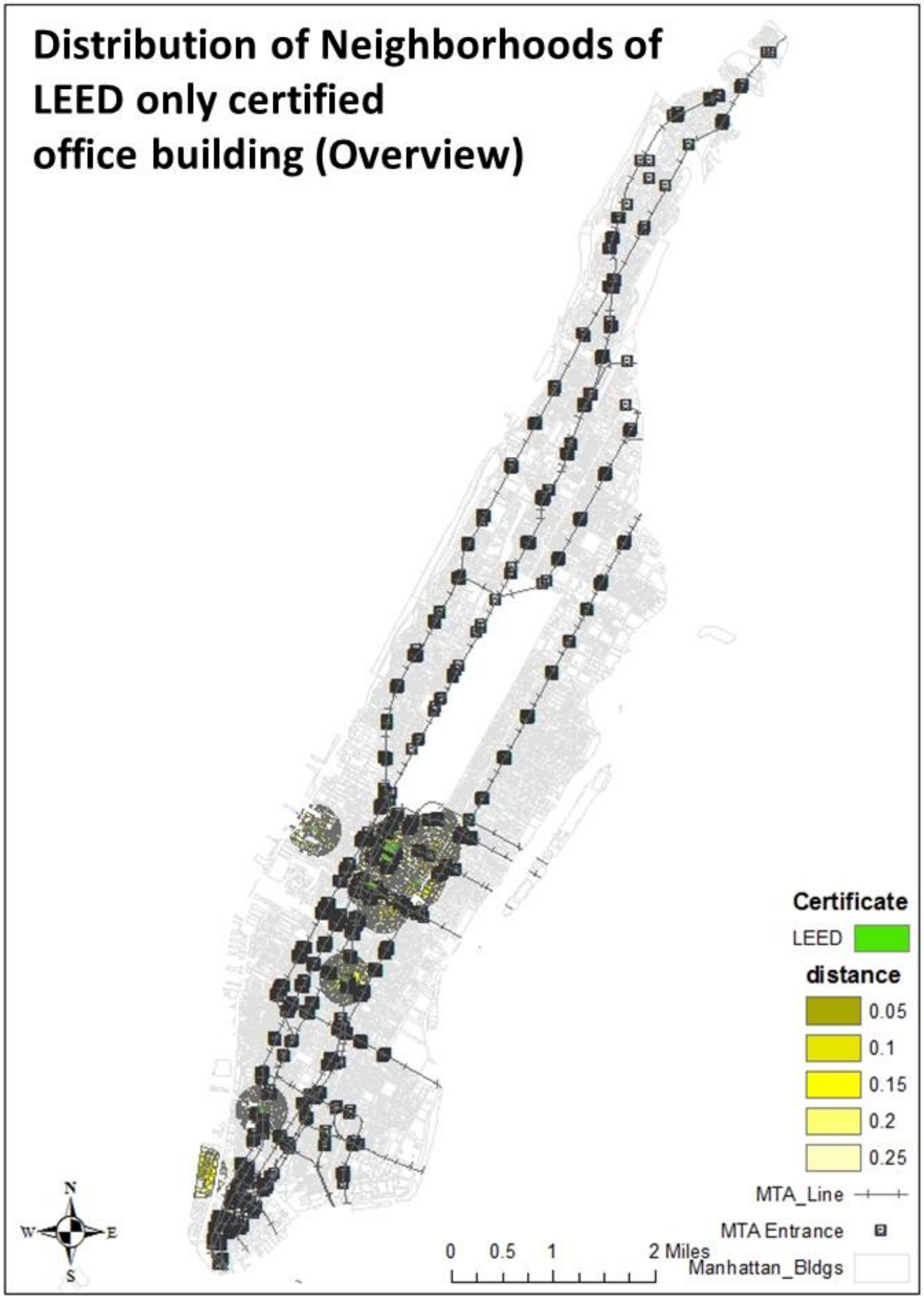

Figure 5.20. Distribution of neighborhoods of LEED only certified office buildings in Manhattan NYC (Overview)

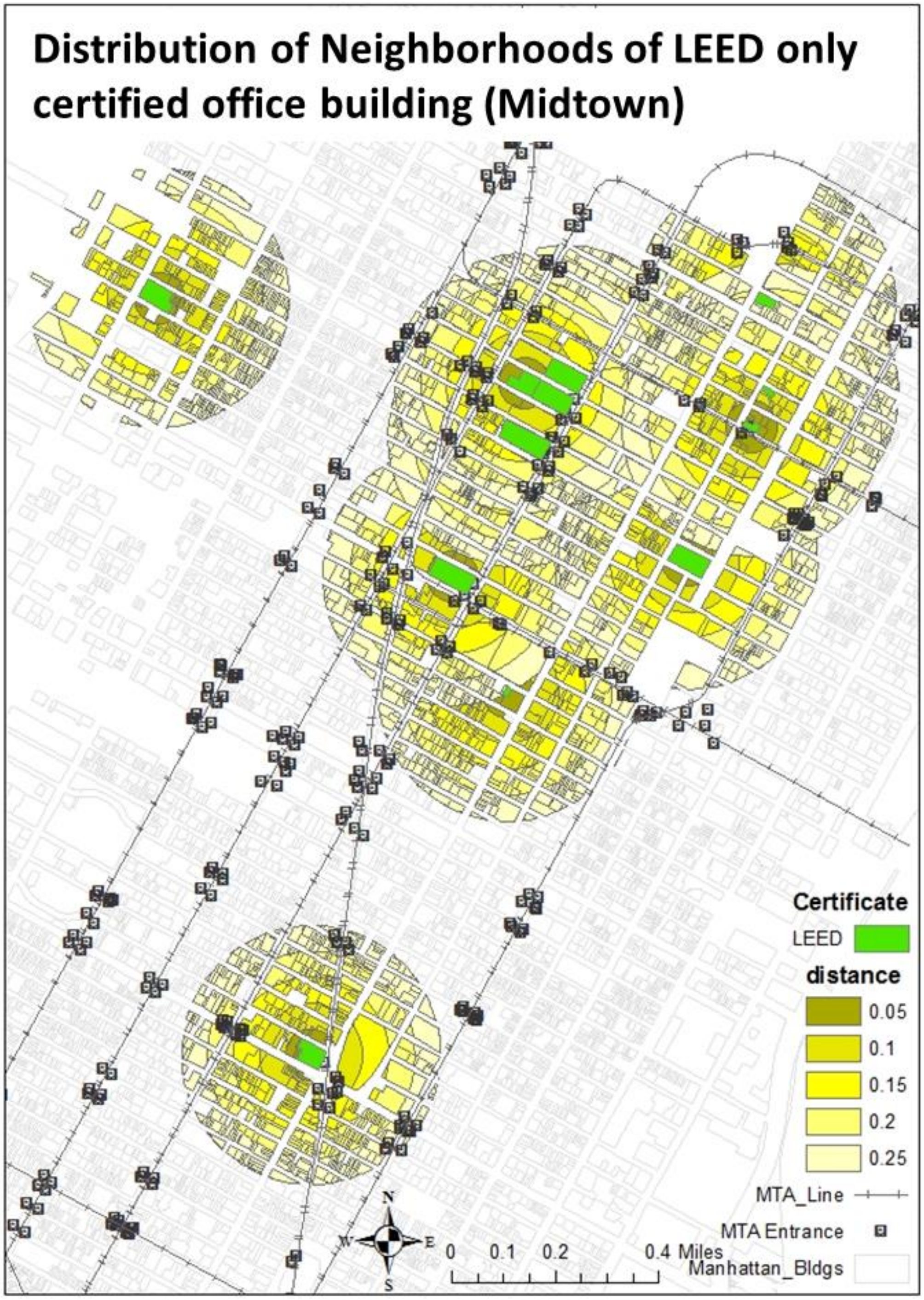

Figure 5.21. Distribution of neighborhoods of LEED only certified office buildings in Midtown Manhattan

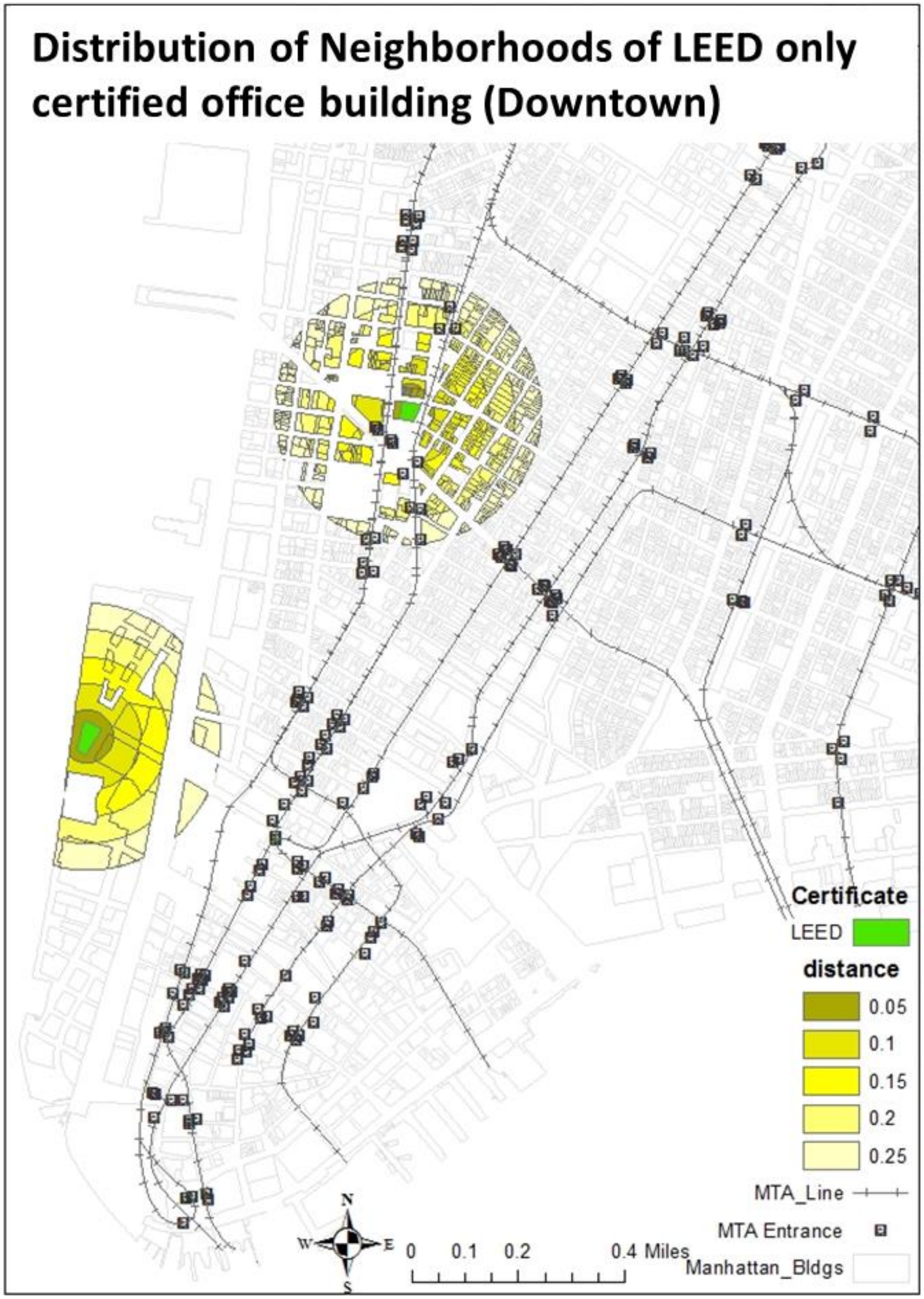

Figure 5.22. Distribution of neighborhoods of LEED only certified office buildings in Downtown Manhattan

Statistical approaches

The statistical approaches applied here consisted of two analyses: a descriptive analysis and a regression analysis. Both analyses utilized the numerical data sets exported from the results of the earlier geographical approach using ArcGIS 10.1. The exported data sets used the CSV format, and could thus be directly imported into the simulation tool, R-Project 3.0.2, without the need for any format changes. The descriptive analysis examined the trends in the numerical data sets with fundamental statistical values, and the regression approach looked at the correlations between pairs of independent and dependent variables to determine the significance level and the strength of the correlation.

- Descriptive analysis

In general, the descriptive analysis examined interesting trends in the data sets, and provided a useful overview of the data sets. The descriptive analysis began by determining the number of certified buildings with each level of LEED certification coverage and its LEED certification level, as well as the number of buildings achieving Energy Star certification from 2007 through 2013, as shown in Tables 5.9 to 5.11 below.

The data presented in Tables 5.9 and 5.10 indicated that most of the office buildings that were originally LEED certified for only part of the building went on to achieve LEED certification for the whole building. Fifteen of the sixty office buildings which achieved LEED certification achieved LEED certifications at least twice for part or all of the building in Manhattan, NYC. The number of office buildings which achieved LEED certification increased over time, and most of the LEED certified buildings achieved the first three LEED certification levels, Certified, Silver and Gold, with full LEED certification coverage for the whole building. Interestingly, only two LEED certified office buildings achieved the highest LEED certification level, Platinum, for their building in 2013, and ten office buildings where only part of the building was originally certified subsequently re-achieved LEED certification for the whole building. Also, three office buildings that had already achieved LEED certification for part of building gained another LEED certification for the whole building to upgrade the coverage of their LEED certification. Moreover, as the data in Table 5.8 show, three office buildings that had already achieved LEED certification for the whole building upgraded their LEED certification by moving up to a higher certification level. The number of Energy Star certified office buildings in Table 5.11 shows trends in Energy Star certification status annually.

Table 5.9. The annual number of LEED only or LEED and Energy Star certified office buildings by LEED certification coverage from 2007 through 2013

	2007	2008	2009	2010	2011	2012	2013
Partial LEED certification	0	0	1	4	4	3	3
Full LEED certification	1	1	11	22	36	44	57
Total number of LEED certification	1	1	12	26	40	47	60
Adding higher LEED certification level of partial LEED certification to existing full LEED certification	0	0	0	0	2	1	7
Adding full LEED certification to existing partial LEED certification	0	0	0	0	1	1	1
Adding higher LEED certification level of full LEED certification to existing full LEED certification	0	0	1	0	0	1	1

Table 5.10. The annual number of buildings with each LEED certification level from 2007 through 2013

	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

Table 5.10 (Continued). The annual number of buildings with each LEED certification level from 2007 through 2013

	2007	2008	2009	2010	2011	2012	2013
Total number of LEED certification levels	1	1	12	26	40	47	60
Upgrading LEED certification level based on the full LEED certification coverage	0	0	1	0	0	1	1

Table 5.11. The annual number of buildings achieving Energy Star certification from 2007 through 2013

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

In general, the number of Energy Star certification tended to increase after 2007, but then started to decrease in 2013, dropping from 78 in 2012 to 66 in 2013. In particular, the number of lapsed Energy Star certifications increased dramatically, exceeding the number of new Energy Star certifications. The number of Energy Star certification renewals also decreased by 12 compared with the previous year, 2012. Energy Star certified buildings are required to renew their certifications annually, including a re-evaluation of actual building performance data based on a building's energy and water consumption during the certified year. The Energy Star certification requirements changed in 2012, which might be one reason for the major drop-off in 2013. In many cases, building stakeholders appeared to abandon their Energy Star certification, although in some cases the actual building performance may not have been able to satisfy the new requirements laid down in the evaluation criteria, which would cause the building to lose its certification. In addition, a particular Energy Star certified office building which lost its Energy Star certification could re-achieve Energy Star certification when the office building was satisfied with all requirements and conditions to be Energy Star certified office building, regardless of the certified year and the lapsed year. Figure 5.23 depicts this change in the number of different LEED certification levels achieved over time, and Figure 5.24 shows the trend in Energy Star certification status over time.

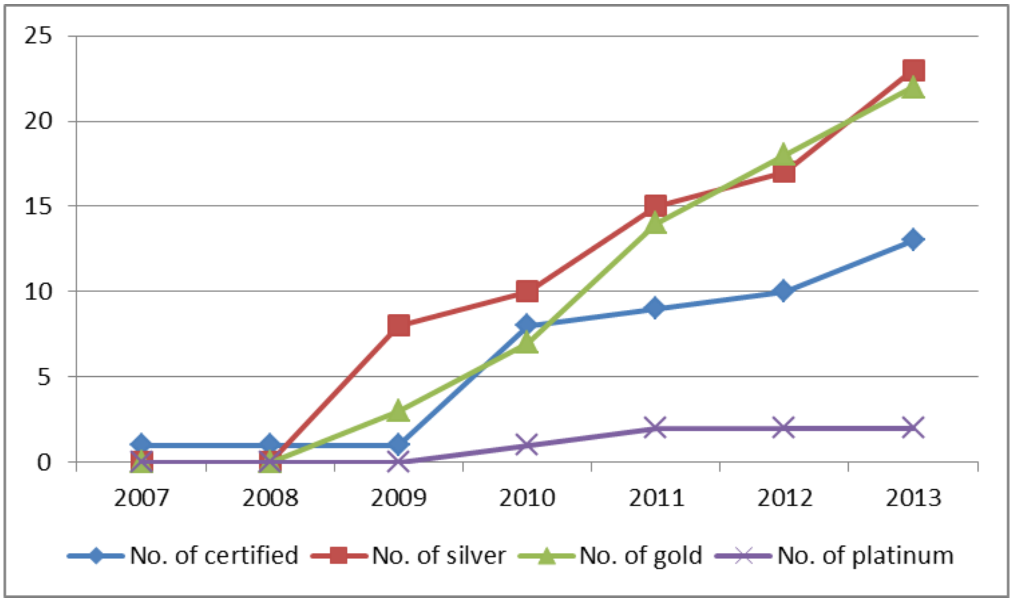

Figure 5.23. Number of buildings achieving each LEED certification level from 2007 through 2013

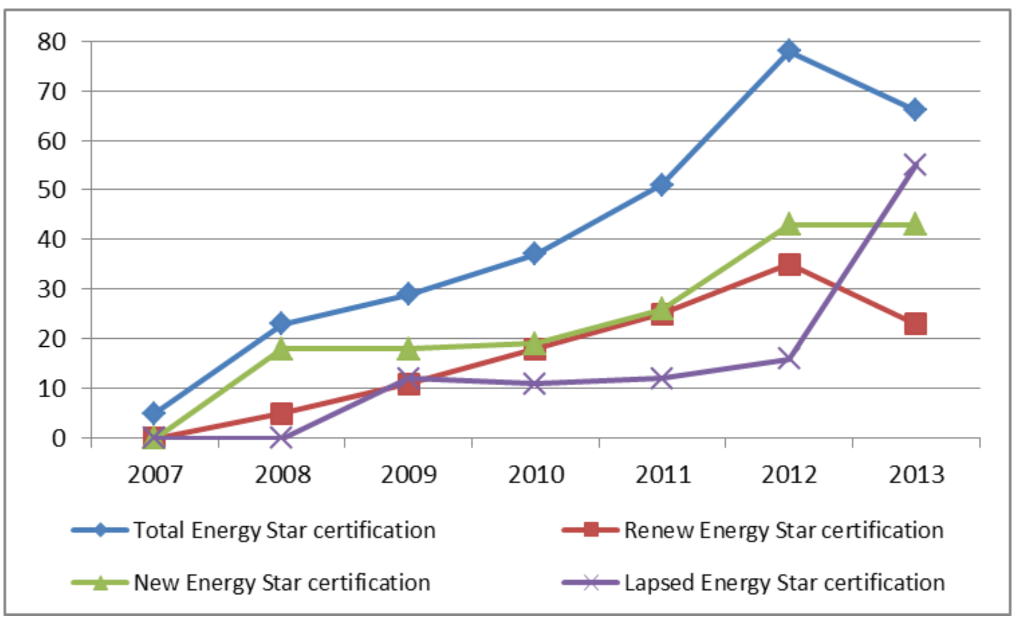

Figure 5.24. Number of buildings with each Energy Star certification status from 2007 through 2013

The descriptive analysis also provided a useful summary of the changes in the median unit market values of all the sub-neighborhoods surrounding the LEED and/or

Energy Star certified office buildings in the study from 2007 through 2013, focusing on five values: the minimum and the maximum values, the mean and the median values, and the standard deviation. In Figure 5.25, the median values and the mean values from 2007 through 2013 presented very similar unit market price patterns for all the sub-neighborhoods, and the mean values for all the sub-neighborhoods over time were always higher than the corresponding median values.

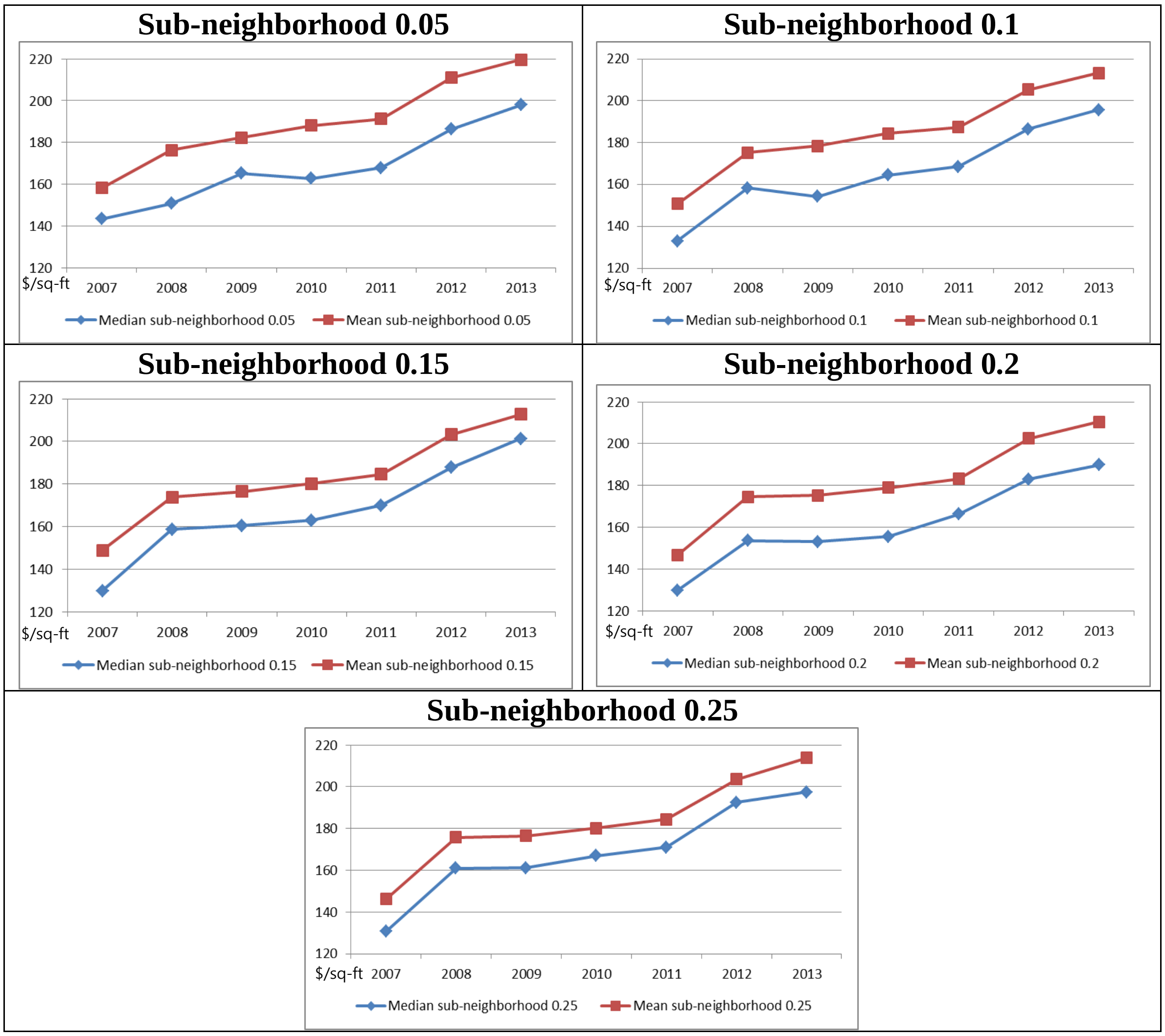

Figure 5.25. Difference in the median and mean values for each sub-neighborhood over time

- Regression analysis

The correlation between the unit market values of the LEED and/or Energy Star certified office buildings and the median unit market values of the buildings in the five sub-neighborhoods surrounding them was examined to reveal any pattern between the two variables and identify an appropriate statistical approach model, either linear or non-linear, for the further regression process. In this study, the correlation between the two variables was investigated for two different considerations, five different sub-neighborhoods and seven research years using Microsoft Excel. The results of the correlation between the two variables indicated a linear correlation for both considerations, as shown in Figures 5.26 and 5.27. Therefore, the further regression models, hedonic price model and linear mixed effect model, were all developed based on a linear correlation.

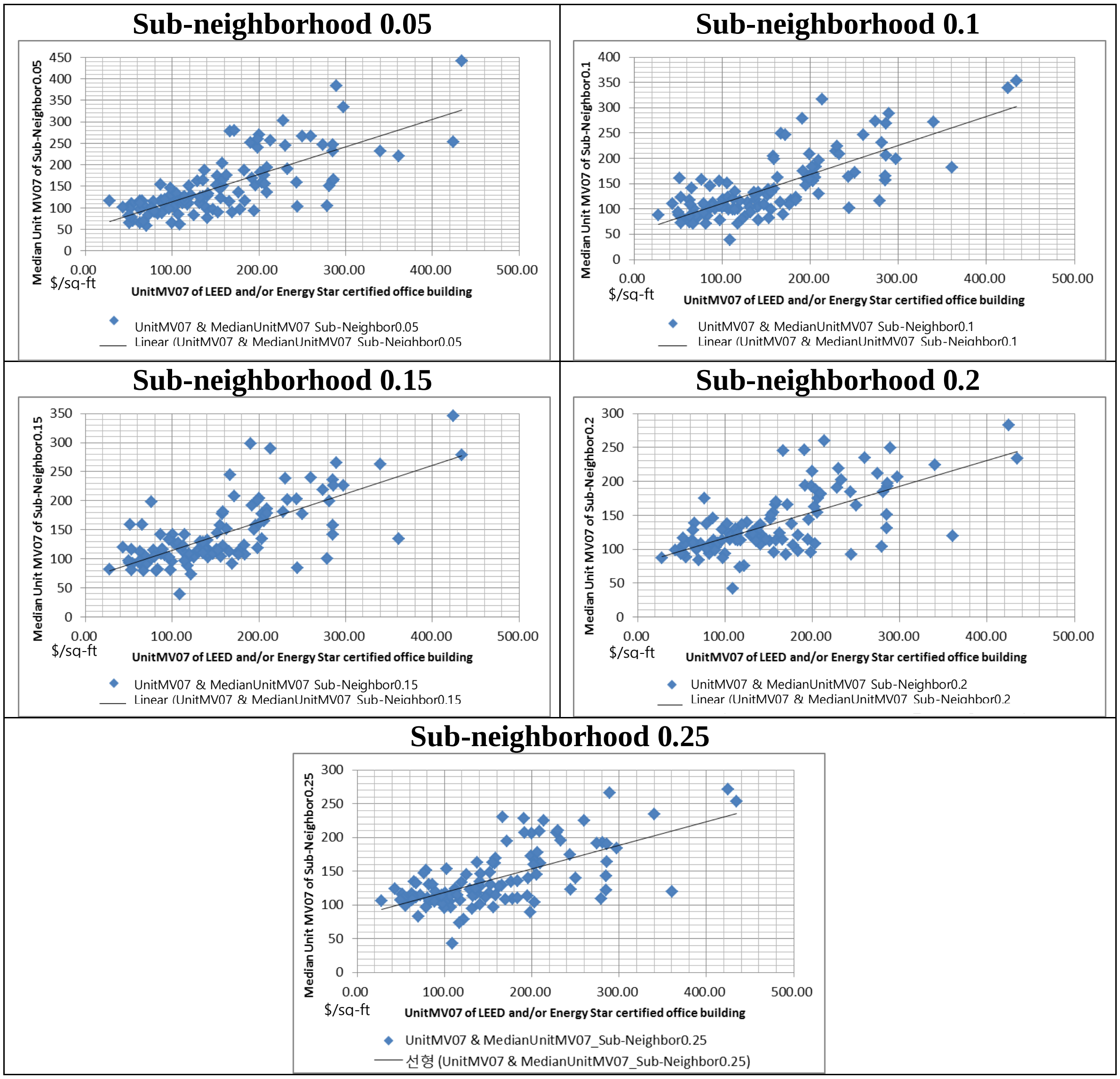

Figure 5.26. Linear correlation between the unit market value of a LEED and/or Energy Star certified office building ($/sq-ft) and the median unit market value of buildings ($/sq-ft) in its five surrounding sub-neighborhoods in the same year (FY 2007)

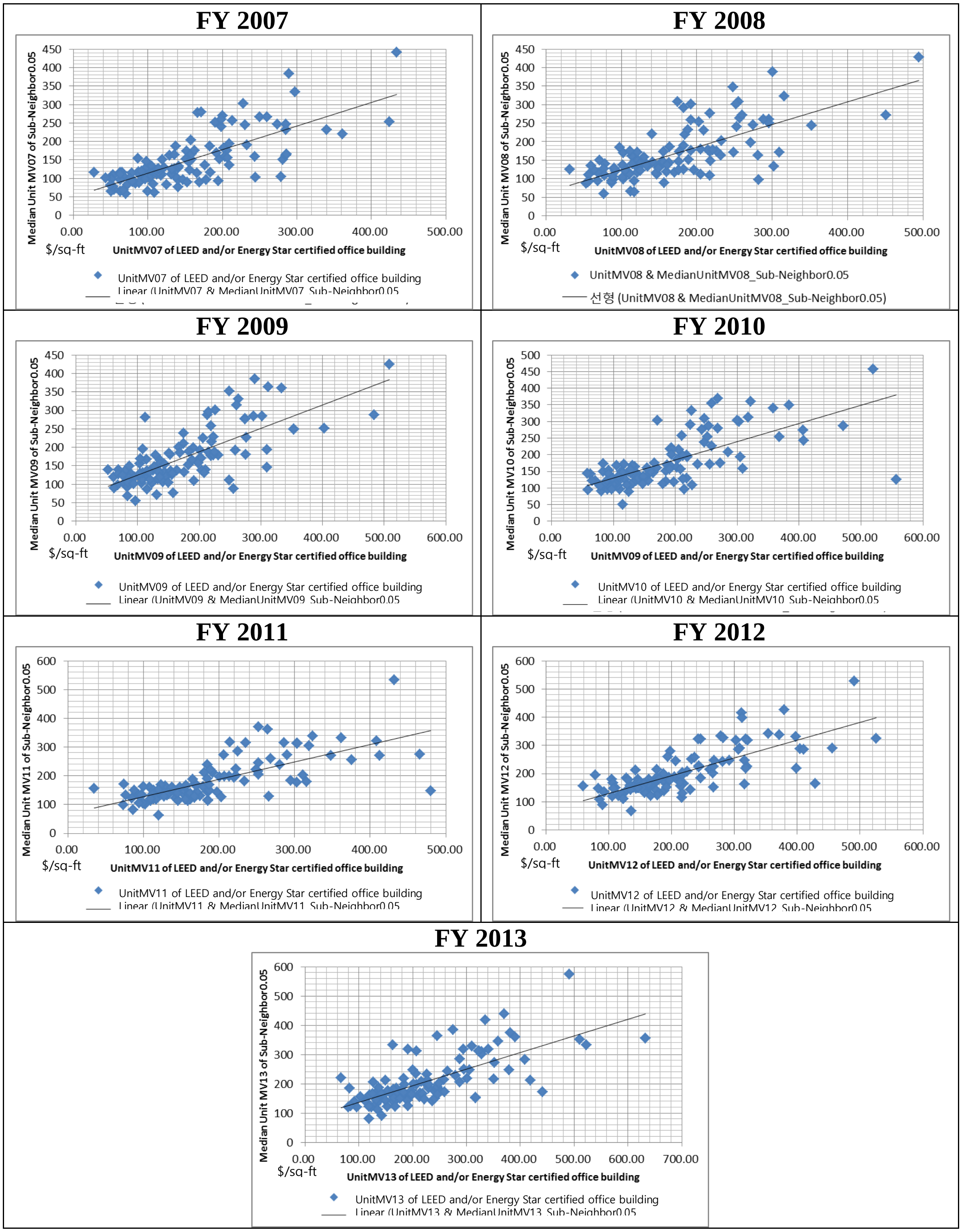

Figure 5.27. Linear correlation between the unit market value of a LEED and/or Energy Star certified office building ($/sq-ft) and the median unit market value of buildings ($/sq-ft) in the closest sub-neighborhood (Sub-neighborhood 0.05) from 2007 through 2013

Based on the linear correlation between the unit market value of a LEED and/or Energy Star certified office building and the median unit market value of buildings in the five surrounding sub-neighborhoods from 2007 through 2013, the results of the regression analysis indicated that there was indeed a correlation between the median unit market value of buildings in each radius neighborhood and that of the LEED and/or Energy Star certified office building. Moreover, this correlation could create various spillover effects, strength and direction, of the LEED and/or Energy Star certified office building on the median unit market value in each sub-neighborhood through the coefficients in the regression result. This suggested that the median unit market value of each sub-neighborhood surrounding a LEED and/or Energy Star certified office building played a role as a dependent variable in this research, and those variables that were related to LEED and Energy Star certification should be taken as the independent variable. This regression analysis consisted of two regression models as mentioned earlier: the hedonic price model and the linear mixed effect model. The hedonic price model was helpful when deciding the most appropriate linear equation to maximize the R^2 value, and the linear mixed effect model indicated the significance of variables and the strength and direction of the correlation between the dependent variable and the independent variable. Both regression models were operated with the whole data sets by the statistical computing tool, R-Project 3.0.2, for a total of ten times, once for each regression model for each sub-neighborhood. Table 5.12 shows the regression models for each different radius-sub-neighborhood and describes the goal of each.

Table 5.12. Goals of each model for each sub-neighborhood

Sub-neighborhood	Model	Goal
Sub-neighborhood 0.05	Hedonic price model	Highest R^2 value for the 0.05 sub-neighborhood to achieve the required value transformation
	Linear mixed effect model	Strength and direction of correlation for the 0.05 sub-neighborhood
Sub-neighborhood 0.1	Hedonic price model	Highest R^2 value for the 0.1 sub-neighborhood to achieve the required value transformation
	Linear mixed effect model	Strength and direction of correlation for the 0.1 sub-neighborhood
Sub-neighborhood 0.15	Hedonic price model	Highest R^2 value for the 0.15 sub-neighborhood to achieve the required value transformation
	Linear mixed effect model	Strength and direction of correlation for the 0.15 sub-neighborhood
Sub-neighborhood 0.2	Hedonic price model	Highest R^2 value for the 0.2 sub-neighborhood to achieve the required value transformation
	Linear mixed effect model	Strength and direction of correlation for the 0.2 sub-neighborhood
Sub-neighborhood 0.25	Hedonic price model	Highest R^2 value for the 0.25 sub-neighborhood to achieve the required value transformation
	Linear mixed effect model	Strength and direction of correlation for the 0.25 sub-neighborhood

This research therefore developed five results for the hedonic price model and five for the linear mixed effect model.

1) R^2 value of sub-neighborhoods of LEED and/or Energy Star certified office buildings

The correlation between the unit market value of a LEED and/or Energy Star certified office building and the median unit market value of buildings in its closest 0.05 sub-neighborhood is 0.715, and the model for this sub-neighborhood does not need to transform the values from the linear equation to any of the other equation options because there was no substantial difference with respect to the correlation or the coefficient determined by the R^2 value for a linear equation or a log-log equation, which had the highest R^2 value in this model. Moreover, the R^2 values for the remaining sub-neighborhoods indicated that the linear hedonic price model equation was more suitable than any of the other hedonic price model equations that could be applied to transform the independent and/or dependent values with the mathematical symbol, log. As a result, the further regression processes, as well as the linear mixed effect model, were based on the linear hedonic price model equation without any transformations. All R^2 values were summarized in Table 5.13.

Table 5.13. R^2 values for the four hedonic price model equation options

Sub-neighborhood	Transformation	Linear	Log-linear	Semi-log	Log-log
Sub-neighborhood 0.05	R^2 value	0.52	0.5125	0.5075	0.5254
	Adjusted R^2 value	0.51	0.5023	0.4972	0.5155
Sub-neighborhood 0.1	R^2 value	0.5742	0.5279	0.5416	0.5192
	Adjusted R^2 value	0.5653	0.5181	0.5321	0.5092
Sub-neighborhood 0.15	R^2 value	0.5287	0.4796	0.4805	0.4529
	Adjusted R^2 value	0.5189	0.4688	0.4697	0.4415
Sub-neighborhood 0.2	R^2 value	0.4682	0.4221	0.4366	0.4014
	Adjusted R^2 value	0.4572	0.4101	0.4248	0.3889
Sub-neighborhood 0.25	R^2 value	0.4095	0.369	0.363	0.3328
	Adjusted R^2 value	0.3972	0.3559	0.3498	0.3189

Based on the resulting R^2 values, the linear mixed effect model used to analyze the correlation between the median unit market values of buildings in the sub-neighborhoods and the unit market value of a LEED and/or Energy Star certified office building is based on the linear hedonic price model equation, which indicates that the data sets for the dependent and independent variables could be directly applied to the linear mixed effect model without the need to transform the data using natural logarithms. These linear mixed effect models also implemented several steps to reveal the effect of a LEED and/or Energy Star certified office building on the median unit market value of buildings in each sub-neighborhood surrounding the LEED and/or Energy Star certified office building for this research. These steps were as follows:

- Linear mixed effect model for the achievement of LEED and/ or Energy Star certifications for each sub-neighborhood.

- Linear mixed effect model for the level of LEED certification for each sub-neighborhood.

- Linear mixed effect model for the coverage of LEED certification for each sub-neighborhood.

The model equation sought the effect of achieving LEED and/or Energy Star certification on the median unit market value in each sub-neighborhood located from within a 0.05 mile radius out to a 0.25 mile radius of the certified building. This model provided the strength and the direction of the resulting impact numerically. This model equation took the following form:

$$Y_{prox} = \beta_0 + \beta_1 X_{uni} + \beta_2 X_{LEED\ certification} + \beta_3 X_{Energy\ Star\ certification} + \alpha_0 + \alpha_1 b + \varepsilon$$

where Y was the median unit market value of the buildings in each sub-neighborhood, X_{unit} indicated the unit market value of the LEED and/or Energy Star certified office building, and $X_{LEED\ certification}$ and $X_{Energy\ Star\ certification}$ were independent variables which had a value of either 1 (Achievement) or 0 (No achievement). β_ns are the coefficients for fixed effect and α_ns are the coefficients for random effects for buildings, and this research was interested in only the coefficients for fixed effects. *prox* indicated each sub-neighborhood from within 0.05 miles of the certified building out to 0.25 miles, with values of 0.05, 0.1, 0.15, 0.2, and 0.25.

The results of the linear mixed effect models for each sub-neighborhood represented the significance of the variables and the strength and the direction of the effect of the LEED and/or Energy Star certified office building. The results are summarized in Table 5.14 below.

Table 5.14. Summary of the results of the linear mixed effect model of the impact of a LEED and/or Energy Star certified building for the five sub-neighborhoods

Sub-neighborhood	Independent variable	Estimated coefficient	p-value
Sub-neighborhood 0.05	Intercept	120.88750	< 0.0001
	Unit market value of LEED and/or Energy Star certified office building	0.29968	< 0.0001
	Energy Star certification achievement	13.19413	< 0.0001
	LEED certification achievement	15.57698	< 0.0001
Sub-neighborhood 0.1	Intercept	126.35415	< 0.0001
	Unit market value of LEED and/or Energy Star certified office building	0.24808	< 0.0001
	Energy Star certification achievement	13.00518	< 0.0001
	LEED certification achievement	18.51467	< 0.0001
Sub-neighborhood 0.15	Intercept	124.52713	< 0.0001
	Unit market value of LEED and/or Energy Star certified office building	0.24917	< 0.0001
	Energy Star certification achievement	12.69110	< 0.0001
	LEED certification achievement	17.13150	< 0.0001
Sub-neighborhood 0.2	Intercept	123.90538	< 0.0001
	Unit market value of LEED and/or Energy Star certified office building	0.24706	< 0.0001
	Energy Star certification achievement	13.71889	< 0.0001
	LEED certification achievement	15.58286	< 0.0001
Sub-neighborhood 0.25	Intercept	125.55475	< 0.0001
	Unit market value of LEED and/or Energy Star certified office building	0.24293	< 0.0001
	Energy Star certification achievement	14.67680	< 0.0001
	LEED certification achievement	17.06417	< 0.0001

According to the above results, the fitted linear mixed effect model equations for each sub-neighborhood were as follows:

Median unit market value of sub-neighborhood$_{0.05}$ *= 120.88750 + 0.29968 x Unit market value of LEED and/or Energy Star certified office building + 15.57698 x (LEED certification achievement) + 13.19413 x (Energy Star certification achievement) +* $\alpha_0 + \alpha_1 b$

Median unit market value of sub-neighborhood$_{0.1}$ *= 126.35415 + 0.24808 x Unit market* *value of LEED and/or Energy Star certified office building + 18.51467 x (LEED certification achievement) + 13.00518 x (Energy Star certification achievement) +* α_0 + $\alpha_1 b$

Median unit market value of sub-neighborhood$_{0.15}$ *= 124.52713 + 0.24917 x Unit market value of LEED and/or Energy Star certified office building + 17.13150 x (LEED certification achievement) + 12.69110x (Energy Star certification achievement) +* α_0 + $\alpha_1 b$

Median unit market value of sub-neighborhood$_{0.2}$ *= 123.90538 + 0.24706 x Unit market value of LEED and/or Energy Star certified office building + 15.58286 x (LEED certification achievement) + 13.71889 x (Energy Star certification achievement) +* α_0 + $\alpha_1 b$

Median unit market value of sub-neighborhood$_{0.25}$ *= 125.55475 + 0.24293 x Unit market value of LEED and/or Energy Star certified office building + 17.06417 x (LEED certification achievement) + 14.67680 x (Energy Star certification achievement) +* α_0 + $\alpha_1 b$

Note: α_0 and α_1 are the estimated coefficients for the random effect of individual certified buildings

The changes in the strength of the impact of the independent variables for each sub-neighborhood are shown in Figures 5.28 and 5.29.

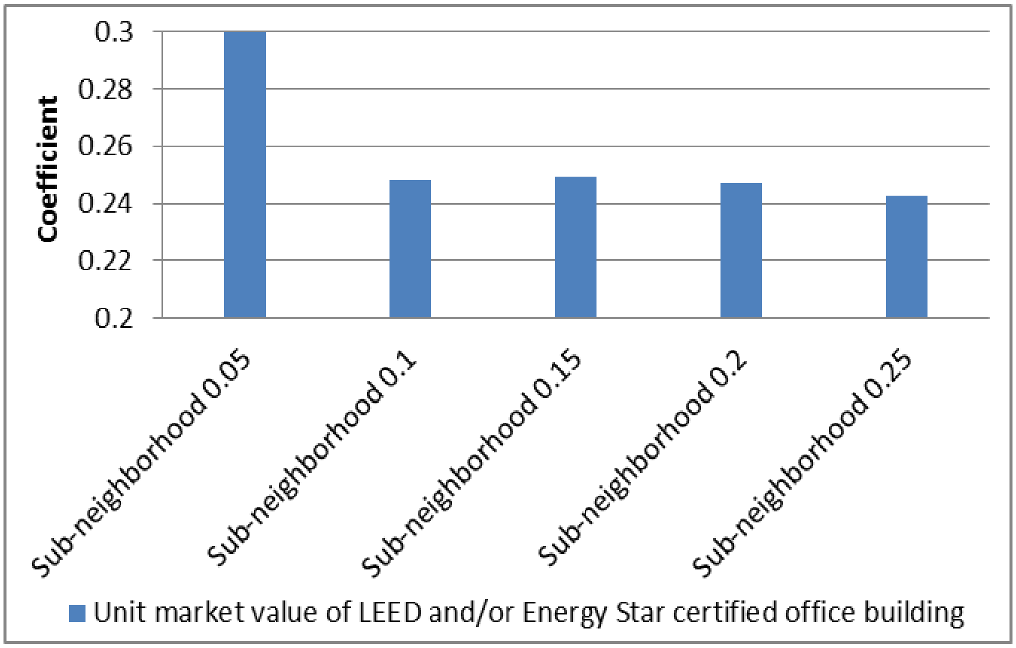

Figure 5.28. The strength of the impact of the unit market value of a LEED and/or Energy Star certified office building on other neighborhood buildings with different proximities

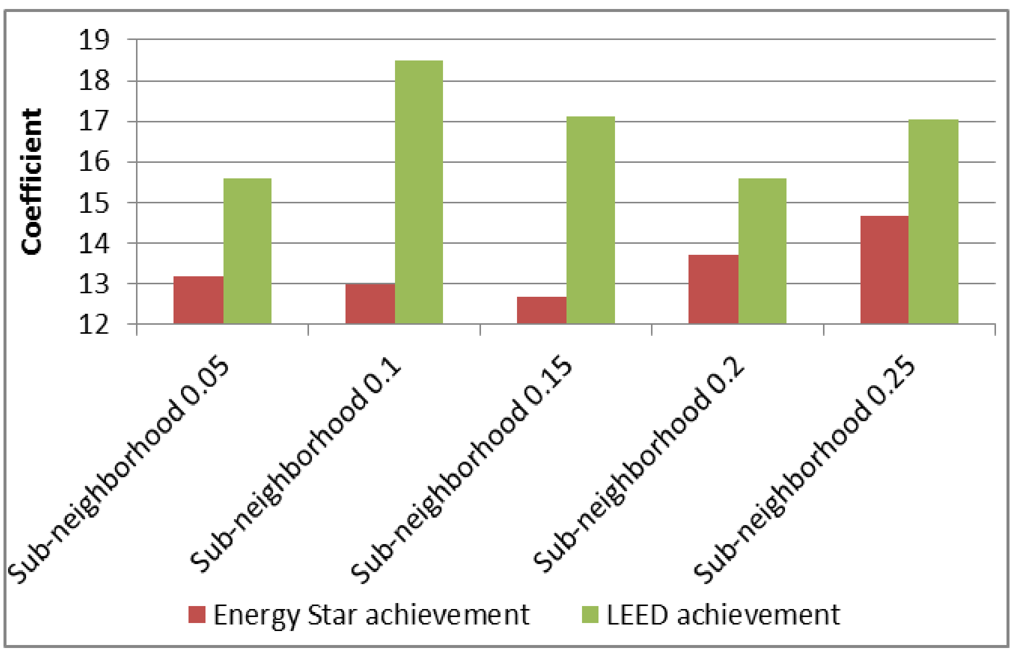

Figure 5.29. The strength of the impact of the achievement of LEED or Energy Star certification for neighborhood buildings with different proximities to the certified building

Each coefficient of the linear mixed effect model equations indicated the strength and the direction of the effect of the LEED and/or Energy Star certified office building without any transformation of values; thus, all the independent variables had a positive impact on the dependent variable irrespective of the five different proximities to the LEED and/or Energy Star certified office building. Specifically, the greatest impact of the unit market value of a LEED and/or Energy Star certified office building was on the median unit market value of the sub-neighborhood 0.05, and this impact decreased sharply for sub-neighborhood 0.1 and then remained fairly consistent for the sub-neighborhoods that were further out. In contrast, the strength of the impact of Energy Star certification achievement initially increased as the distance from the certified building decreased. The strength of the impact of LEED certification achievement was higher than that of Energy Star certification achievement in all sub-neighborhoods over time. However, it was difficult to interpret the results for the strength of the impact of LEED certification achievement because it appeared to fluctuate widely during the research period in the five sub-neighborhoods. Therefore, the strength of the impact on the unit market value of a LEED and/or Energy Star certified office building and the proximity of different sub-neighborhoods were directly proportional to each other, while the strength of the impact of Energy Star certification achievement alone was inversely proportional to the proximity of neighborhood according to these results. Additionally, although the simple fact of a building achieving a LEED certification provided a positive impact on the median unit market value of the buildings in all the sub-neighborhoods, it was hard to identify a strong relationship between the strength of the impact of LEED certification achievement on the median unit market value of all sub-neighborhoods and the proximity to an office building that achieved LEED certification.

2) Linear mixed effect model for the impact of different LEED certification levels on the five sub-neighborhoods

This linear mixed effect model equation analyzed the effect of LEED certification levels on the median unit market value for each sub-neighborhood based on five different proximities to LEED only or LEED and Energy Star certified office buildings. The LEED certification levels became an independent variable in this model; thus, the result of this model presented the strength of the impact of each different LEED certification level on median unit market value of each sub-neighborhood in detail. The basic model equation was as follows:

$$Y_{prox} = \beta_0 + \beta_1 X_{unit} + \beta_2 X_{LEED\ certification\ level} + \alpha_0 + \alpha_1 b + \varepsilon$$

where Y was the median unit market value of each sub-neighborhood, X_{unit} was the unit market value of the LEED only or LEED and Energy Star certified office building, and $X_{LEED\ certification\ level}$ was an independent variable which has a value from 1 (Certified) through 4 (Platinum) depending on the LEED certification level. β_n's were the coefficients of the fixed effects and were the focus of attention in this model and α_n's were the coefficients of the random effects for the buildings. *prox* indicated the five different sub-neighborhoods which were based on their proximity to the office buildings which achieved LEED certification.

The results of linear mixed effect models for each sub-neighborhood were summarized in Table 5.15.

Table 5.15. Summary of the results of the linear mixed effect model of LEED certification levels for the five sub-neighborhoods

Sub-neighborhood	Independent variable	Estimated coefficient	P-value
Sub-neighborhood 0.05	Intercept	112.37771	< 0.0001
	Unit market value of LEED only and LEED and Energy Star certified office building	0.36007	< 0.0001
	Certified level	14.87196	0.0027
	Silver level	16.72665	< 0.0001
	Gold level	19.23242	< 0.0001
	Platinum level	-64.40940	< 0.0001
Sub-neighborhood 0.1	Intercept	119.97461	< 0.0001
	Unit market value of LEED only and LEED and Energy Star certified office building	0.29751	< 0.0001
	Certified level	13.53493	0.0010
	Silver level	19.26639	< 0.0001
	Gold level	23.45724	< 0.0001
	Platinum level	-29.88993	0.0049
Sub-neighborhood 0.15	Intercept	118.21648	< 0.0001
	Unit market value of LEED only and LEED and Energy Star certified office building	0.29757	< 0.0001
	Certified level	12.11061	0.0035
	Silver level	22.78399	< 0.0001
	Gold level	17.84525	< 0.0001
	Platinum level	-37.16143	0.0005
Sub-neighborhood 0.2	Intercept	117.74758	< 0.0001
	Unit market value of LEED only and LEED and Energy Star certified office building	0.29611	< 0.0001
	Certified level	10.51142	0.0093
	Silver level	19.08575	< 0.0001
	Gold level	18.82203	< 0.0001
	Platinum level	-41.16570	0.0001
Sub-neighborhood 0.25	Intercept	119.69300	< 0.0001
	Unit market value of LEED only and LEED and Energy Star certified office building	0.29174	< 0.0001
	Certified level	14.45864	< 0.0001
	Silver level	19.48846	< 0.0001
	Gold level	20.02317	< 0.0001
	Platinum level	-39.14775	< 0.0001

According to the result shown in Table 5.13, all the independent variables were significant for all median unit market values of sub-neighborhoods, as indicated by the significance level of the LEED certification level and the unit market value of office buildings which achieved LEED certification for each sub-neighborhood being below the significance level of 0.05. Moreover, three of the LEED certification levels, Certified, Silver and Gold, had a positive estimated coefficient for all sub-neighborhoods, while the highest LEED certification level, Platinum, had a negative estimated coefficient for all sub-neighborhoods, from sub-neighborhood 0.05 through sub-neighborhood 0.25, in this linear mixed effect model. Figure 5.30 describes the pattern for the strength of the unit market values of office buildings that achieved LEED certification for each sub-neighborhood, and the strength of the LEED certification levels exhibited a tremendous difference between the first three LEED certification levels and the highest LEED certification level, Platinum, as shown in Figure 5.31.

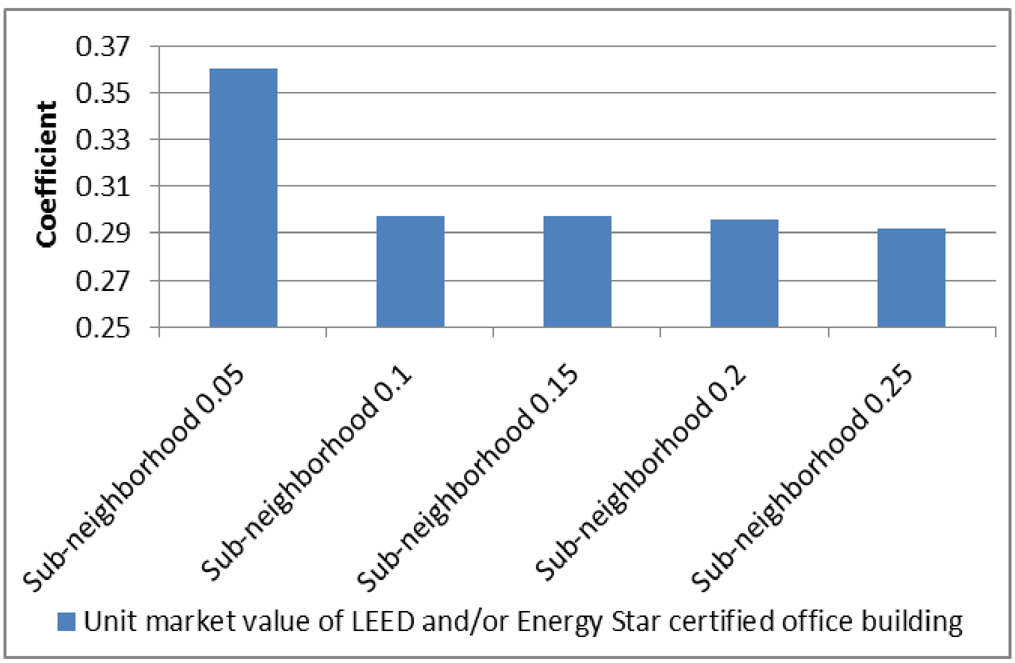

Figure 5.30. Strength of unit market value of LEED only or LEED and Energy Star certified office building for each sub-neighborhood

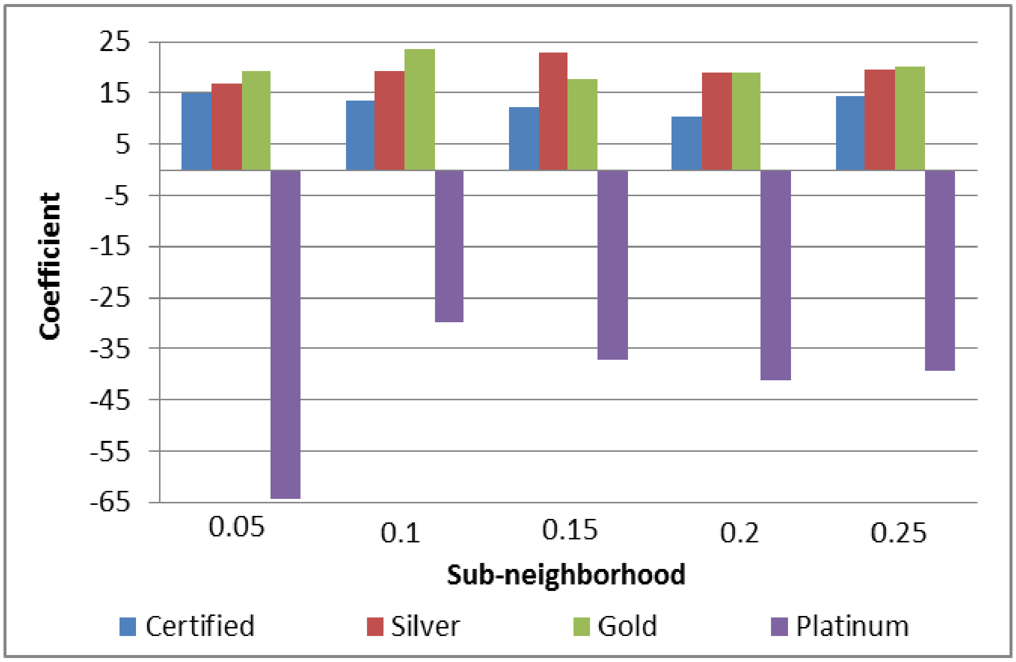

Figure 5.31. Different directions and magnitudes of the impact of LEED certification level

Although the estimated coefficient of LEED Platinum was statistically significant in this model, this was likely due to the extremely small number of buildings in the screened population with the LEED Platinum level (n=2). Even though the p-value for the LEED Platinum level was satisfied with a significance level of 0.05, it is difficult to argue that this is a meaningful correlation given the small number of Platinum buildings in the population. In addition, the pattern of the strength of impact of unit market value of office buildings which achieved LEED certification on the median unit market value of each neighborhood was very similar to the pattern shown in the previous linear mixed effect model where both certifications were considered together. Overall, the positive impact of unit market value of an office building which achieved LEED certification was provided to all sub-neighborhoods, but the positive impact steeply decreased from the sub-neighborhood 0.1 onwards, although a small positive impact was maintained to the outer edge of the walkable neighborhood at 0.25 miles.

For instance, only the Certified level indicated that the greatest impact was felt in the buildings closest to the certified building, namely those located in the sub-neighborhood

0.05, and the strength then decreased steadily with decreasing proximity, although the strength of the impact of the Certified level did increase again slightly for the sub-neighborhood 0.25. The Silver and Gold levels had the greatest impact on sub-neighborhoods 0.1 and 0.15, after which the strength of the impact fades. The changes in the effect of these LEED certification levels are shown in Figure 5.32.

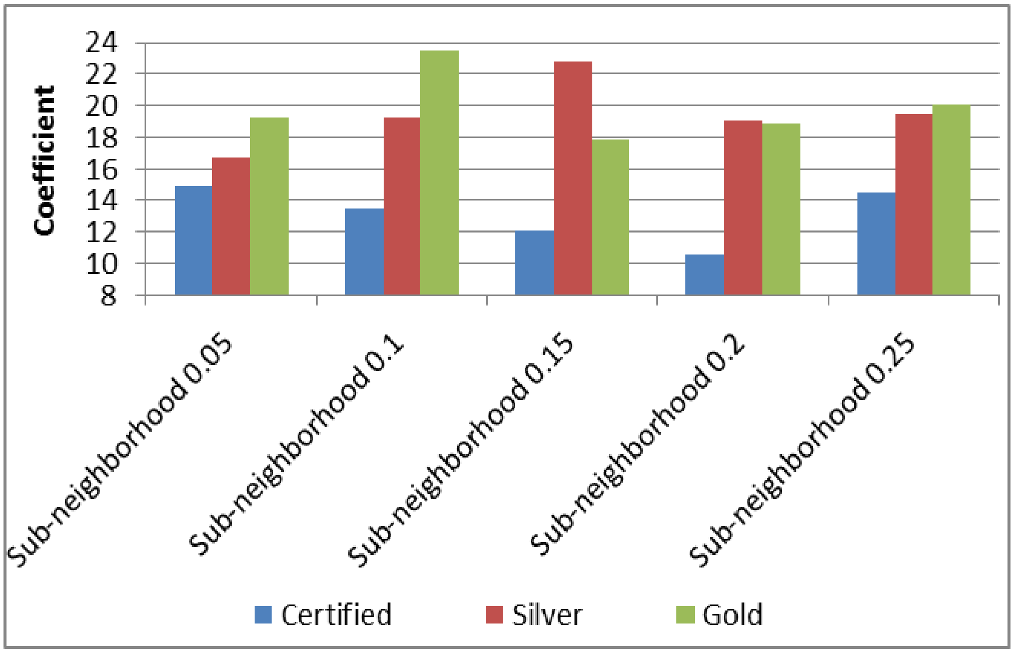

Figure 5.32. Impact of three LEED certification levels for each sub-neighborhood

Note. Figure 5.31 was adapted from Figure 5.30 and modified by excluding the coefficient values of LEED Platinum level to illustrate the trends in the coefficient values for the rest of the LEED certification levels (Certified, Silver, Gold) with decreasing proximity to the certified office buildings more clearly.

Based on these results, the fitted linear mixed effect model equations of LEED certification levels for each sub-neighborhood were as follows:

Median unit market value of sub-neighborhood$_{0.05}$ = *112.37771 + 0.36007 x Unit market value of LEED only or LEED and Energy Star certified office building + 14.87196 x (LEED Certified level) + 16.72665 x (LEED Silver level) + 19.23242 x (LEED Gold level) − 64.40940 x (LEED Platinum level) +* $\alpha_0 + \alpha_1 b$

Median unit market value of sub-neighborhood$_{0.1}$ = *119.97461 + 0.29751 x Unit market value of LEED only or LEED and Energy Star certified office building + 13.53493 x*

(LEED Certified level) + 19.26639 x (LEED Silver level) + 23.45724 x (LEED Gold level) − 29.88993 x (LEED Platinum level) + $\alpha_0 + \alpha_1 b$

Median unit market value of sub-neighborhood$_{0.15}$ *= 118.21648 + 0.29757 x Unit market value of LEED only or LEED and Energy Star certified office building + 12.11061 x (LEED Certified level) + 22.78399 x (LEED Silver level) + 17.84525 x (LEED Gold level) − 37.16143 x (LEED Platinum level) +* $\alpha_0 + \alpha_1 b$

Median unit market value of sub-neighborhood$_{0.2}$ *= 117.74758 + 0.29611 x Unit market value of LEED only or LEED and Energy Star certified office building + 10.51142 x (LEED Certified level) + 19.08575 x (LEED Silver level) + 18.82203 x (LEED Gold level) − 41.16570 x (LEED Platinum level) +* $\alpha_0 + \alpha_1 b$

Median unit market value of sub-neighborhood$_{0.25}$ *= 119.69300 + 0.29174 x Unit market value of LEED only or LEED and Energy Star certified office building + 14.45864 x (LEED Certified level) + 19.48846 x (LEED Silver level) + 20.02317 x (LEED Gold level) − 39.14775 x (LEED Platinum level) +* $\alpha_0 + \alpha_1 b$

3) Linear mixed effect model for the LEED certification coverage from sub-neighborhood 0.05 through sub-neighborhood 0.25

The purpose of this linear mixed effect model was to find the correlation between the median unit market value of each sub-neighborhood and the LEED coverage. The LEED certification coverage indicated that a building achieves LEED certification for part of the building or the whole building. The LEED certification coverage was measured by the numerical values as follows:

	Partial LEED certification (For part of a building)	Full LEED certification (For a whole building)
Numerical value	1	2

Therefore, the median unit market value of each neighborhood of office buildings which achieved LEED certification played a role in the dependent variable and the variables related to the LEED certification should be an independent variable in this model. The model equation took form as below and the results of this model are shown in Table 5.16.

$$Y_{prox} = \beta_0 + \beta_1 X_{unit} + \beta_2 X_{LEED\ certification\ coverage} + \alpha_0 + \alpha_1 b + \varepsilon$$

The meaning of mathematical symbols in this equation was the same as the previous description except $X_{LEED\ coverage}$. The variable $X_{LEED\ certification\ coverage}$ indicated the portion of LEED certification in a LEED certified office building, either LEED certification for part of the building, "Partial LEED certification", and LEED certification for the whole building, "Full LEED certification".

Table 5.16. Summary of the results of the linear mixed effect model for the level of LEED coverage

Sub-neighborhood	Independent variable	Estimated coefficient	p-value
Sub-neighborhood 0.05	Intercept	119.08939	< 0.0001
	Unit market value of LEED only and LEED and Energy Star certified office building	0.32574	< 0.0001
	Partial LEED certification	13.27922	0.1049
	Full LEED certification	16.04229	< 0.0001
Sub-neighborhood 0.1	Intercept	124.51849	< 0.0001
	Unit market value of LEED only and LEED and Energy Star certified office building	0.27420	< 0.0001
	Partial LEED certification	9.11266	0.1764
	Full LEED certification	19.57684	< 0.0001
Sub-neighborhood 0.15	Intercept	122.92818	< 0.0001
	Unit market value of LEED only and LEED and Energy Star certified office building	0.27371	< 0.0001
	Partial LEED certification	6.43062	0.3449
	Full LEED certification	18.31612	< 0.0001
Sub-neighborhood 0.2	Intercept	122.45916	< 0.0001
	Unit market value of LEED only and LEED and Energy Star certified office building	0.27211	< 0.0001
	Partial LEED certification	10.22040	0.125
	Full LEED certification	16.40950	< 0.0001
Sub-neighborhood 0.25	Intercept	124.30755	< 0.0001
	Unit market value of LEED only and LEED and Energy Star certified office building	0.26822	< 0.0001
	Partial LEED certification	11.23730	0.1035
	Full LEED certification	18.00351	< 0.0001

The results of each sub-neighborhood commonly presented that the variables of partial LEED certification for all sub-neighborhoods were not significant because the significant levels of partial LEED certification are greater than the significance level of 0.05. In this p-value, the limited number of partial LEED certified office building in the research area over time likely affected the p-values, which were greater than the significance level of 0.05. In contrast, the rest of the independent variables were significant and showed the pattern of the strength of impact for each neighborhood as shown in Figures 5.33 and 5.34.

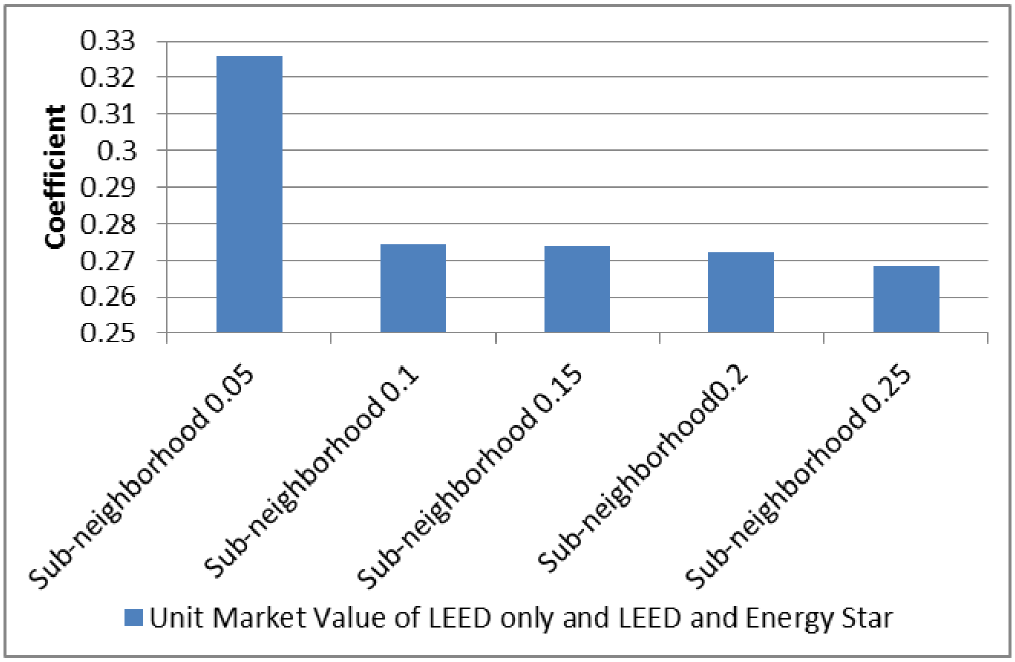

Figure 5.33. Strength of the impact of unit market value of all office buildings with LEED certification for each sub-neighborhood

As shown in Figure 5.33, the strength of the impact of the unit market value of an office building which achieved LEED certification for each sub-neighborhood in this model followed a similar pattern to the previous two models. The strongest impact of unit market value of office buildings with LEED certification existed at the sub-neighborhood 0.05, and the strengths of those impacts for the rest of sub-neighborhoods were almost similar.

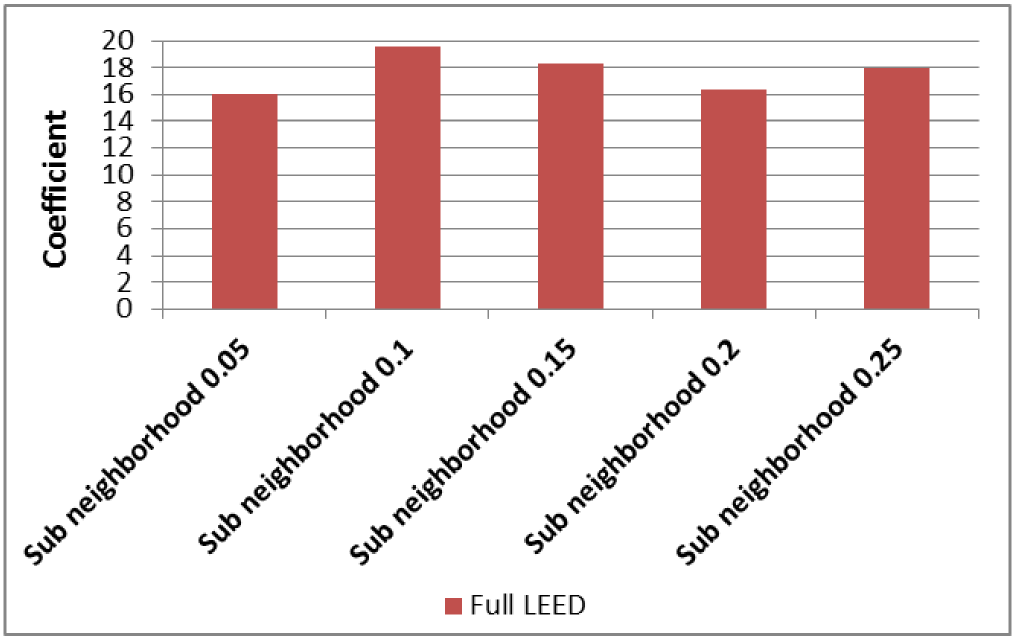

Figure 5.34. Strength of the impact of LEED certification coverage (Full LEED certification) on the median unit market value of each sub-neighborhood

In Figure 5.34, the strength of the impact of full LEED certification was approximately between 16 and 20 for all sub-neighborhoods, and the highest coefficient value was for the zone of sub-neighborhood 0.1. However, the lowest coefficient value was indicated for the zone of sub-neighborhood 0.05. Based on the results of this model, the fitted linear mixed effect model equations of LEED certification coverage for each sub-neighborhood were as follows:

Median unit market value of sub-neighborhood$_{0.05}$ = *119.08939 + 0.32574 x Unit market value of LEED only or LEED and Energy Star certified office building + 16.04229 x (Full LEED certification) + 13.27922 x (Partial LEED certification) +* $\alpha_0 + \alpha_1 b$

Median unit market value of sub-neighborhood$_{0.1}$ = *124.51849 + 0.27420 x Unit market value of LEED only or LEED and Energy Star certified office building + 19.57684 x (Full LEED certification) + 9.11266 x (Partial LEED certification) +* $\alpha_0 + \alpha_1 b$

Median unit market value of sub-neighborhood$_{0.15}$ = *122.92818 + 0.27371 x Unit market value of LEED only or LEED and Energy Star certified office building + 18.31612 x*

(Full LEED certification) + 6.43062 x (Partial LEED certification) + $\alpha_0 + \alpha_1 b$

Median unit market value of sub-neighborhood$_{0.2}$ *= 122.45916 + 0.27211 x Unit market value of LEED only or LEED and Energy Star certified office building + 16.40950 x (Full LEED certification) + 10.22040 x (Partial LEED certification) +* $\alpha_0 + \alpha_1 b$

Median unit market value of sub-neighborhood$_{0.25}$ *= 124.30755 + 0.26822 x Unit market value of LEED only or LEED and Energy Star certified office building + 18.00351 x (Full LEED certification) + 11.23730 x (Partial LEED certification) +* $\alpha_0 + \alpha_1 b$

- Model validation

The model validation was based on the Log-likelihood Ratio Test (LRT) to select between the fitted model and the null model by comparing the values of the AIC (Akaike Information Criterion) and BIC (Bayesian Information Criterion) for both models. As this study considered five sub-neighborhoods over time, each linear mixed effect model required the LRT to be performed five times to consider each of the five sub-neighborhoods for each LEED and/or Energy Star certified office building. Consequently, this study performed four model validations for the four linear mixed effect models between the dependent variable and the independent variables and five LRTs for the five sub-neighborhoods of the LEED and/or Energy Star certified office building. The null model was that the fitness of the fitted model is decreased by adding additional variables to the fitted model, which includes only an intercept, and the hypotheses of LRT for this study were as follows:

H_0*: The null model is true.*

H_1*: The null model is not true.*

1) Linear mixed effect model for the effect of the unit market value of a LEED and/or Energy Star certified office building and the LEED and/or Energy Star certification on each sub-neighborhood surrounding the LEED and/or Energy Star certified office building

The results of the LRT for each sub-neighborhood were as follows: 452.4988 (sub-neighborhood 0.05), 561.2888 (sub-neighborhood 0.1), 587.105 (sub-neighborhood 0.15), 617.9074 (sub-neighborhood 0.2), and 628.2624 (sub-neighborhood 0.25); all p-values for the results were significant. Moreover, the values of AIC and BIC for the fitted models for every sub-neighborhood were consistently smaller than the values of both criteria for the null models of the sub-neighborhoods, which indicates that these fitted models were statistically better than the null models.

2) Linear mixed effect model for the effect of the unit market value of a LEED and/or Energy Star certified office building and the LEED certification level on each sub-neighborhood surrounding the LEED and/or Energy Star certified office building

The values of the Log-likelihood ratio statistics for each sub-neighborhood were as follows: 455.7447 (sub-neighborhood 0.05), 520.0214 (sub-neighborhood 0.1), 558.21 (sub-neighborhood 0.15), 575.1618 (sub-neighborhood 0.2), and 581.4436 (sub-neighborhood 0.25); the p-values of all values of the Log-likelihood ratio statistics were significant because the p-values were all smaller than 0.0001. In addition, the values of AIC and BIC for the fitted models for all the sub-neighborhoods were again consistently smaller than the values of both criteria for the null models of all sub-neighborhoods. Therefore, the fitted models for all the sub-neighborhoods were better than the null models for the sub-neighborhoods in statistical terms.

3) Linear mixed effect model for the effect of the unit market value of a LEED and/or Energy Star certified office building and the LEED certification coverage on each sub-neighborhood surrounding the LEED and/or Energy Star certified office building

The results of the Log-likelihood ratio statistics were 403.7884 (sub-neighborhood 0.05), 479.2448 (sub-neighborhood 0.1), 504.6297 (sub-neighborhood 0.15), 525.6471 (sub-neighborhood 0.2), and 534.8732 (sub-neighborhood 0.25); the p-values of the results were all smaller than 0.0001, which indicates that the results were significant.

Moreover, the fitted models for each sub-neighborhood had smaller values for AIC and BIC than the null models for each sub-neighborhood in this linear mixed effect model, indicating that these fitted models were once again better than the null models in this linear mixed effect model.

Discussion

This research focused on measuring the spillover effect of LEED and/or Energy Star certified office buildings in Manhattan NYC on buildings in their neighborhoods based on their proximity to a certified office building from an economic standpoint for encouraging the mutual growth of LEED and/or Energy Star certified office buildings and buildings in their sub-neighborhoods, a win-win approach. The market values of the buildings concerned, along with details of the LEED and Energy Star certification data such as the major characteristics of LEED certification, were analyzed using both geographical and statistical approaches. The results indicated that there were indeed correlations between the median unit market value of each sub-neighborhood surrounding a LEED and/or Energy Star certified office building and the various features of the LEED and/or Energy Star certification, except when LEED certification was only achieved by part of a building. These correlations also highlighted the positive impact displayed in this data set on the median unit market values of all the sub-neighborhoods that were caused by all types of LEED and/or Energy Star certification except for the LEED Platinum level. In particular, the unit market value of buildings in the sub-neighborhoods of a LEED and/or Energy Star certified office building was directly related to its proximity to that LEED and/or Energy Star certified office building. The greatest impact on the unit market value of neighborhood buildings was on those closest to the certified building, within 0.05 miles, after which the strength of the impact decreased dramatically for the next sub-neighborhood, from 0.05 to 0.1 miles, and then continued to decrease nearly slightly with decreasing proximity. Therefore, the strength of the positive impact of the unit market value of a LEED and/or Energy Star certified office building was reduced in this data set in accordance with a buildings decreasing proximity to LEED and/or Energy Star certified office building, which is in accordance with the expected outcome. However, the remaining independent variables, namely LEED certification level, LEED certification coverage, and LEED and/or Energy Star certification achievement, presented different results regarding the strength of the impact of these independent variables for each sub-neighborhood as a result of changes in a building′s proximity to a LEED and/or Energy Star certified office building. Although these independent variables, whose values are significant and satisfied the sample conditions in this study, did generally appear to have a positive impact on the unit market values of buildings in each sub-neighborhood, these positive impacts on the median unit market value presented irregular curves with no particular systematic pattern based on decreasing proximity to a LEED and/or Energy Star certified office building.

According to the findings of this study, the changes in the unit market value of LEED and/or Energy Star certified office buildings from 2007 through 2013 does have an immediate positive effect on the median unit market values of buildings in the sub-neighborhoods studied, and the strength of the effect of these changes in the unit market value of the LEED and/or Energy Star certified office building exhibited a clear inverse proportional curve with decreasing proximity to a LEED and/or Energy Star certified office building. The features of LEED certification, LEED certification level and coverage (except for the LEED Platinum level) and partial LEED certification, as well as the achievement of LEED and/or Energy Star certification, all displayed a correlation with the median unit market value of buildings in each sub-neighborhood and had a positive impact on their median unit market value as the independent variables. These significant independent variables may be providing an indirect economic impact on the median unit market value of buildings in each sub-neighborhood through changing the unit market value of the LEED and/or Energy Star certified office building. Consequently, the strengths of their correlations with the median unit market value of each sub-neighborhood display non-systematic patterns in the strength of the effect regardless of proximity to a LEED and/or Energy Star certified office building for the period covered by this research.

Limitations

This research was subject to several limitations as follows: (1) The buildings in all sub-neighborhoods are assumed to have homogenous external features in the existing environment, except for the LEED and/or Energy Star certified office building, in terms of measuring the spillover effect of the certified office building. Fundamentally, the market values of most office properties are affected by numerous external features in the environment including economics, politics, social science, and so on. Therefore, these other external features from the various areas could also play a role and should be considered in future studies of the interaction between LEED and/or Energy Star certified office buildings and other external features. (2) The potential impact of a national economic recession, which can be assumed to have an equivalent effect on the overall natural real estate market trends in Manhattan NYC over time. (3) The building owners, investors, and developers are also interested in obtaining a reasonable Return On Investment (ROI), balancing the financial expense for achieving LEED and Energy Star certification with the property value benefits gained from LEED and Energy Star certification. However, this study considered only the property benefits of LEED and Energy Star certification, using the measurement of unit market value to examine the economic benefits of LEED and/or Energy Star certification for an office building. Further research exploring the economic interests of building owners, investors, and developers, as well as the economic benefits to be gained through LEED and/or Energy Star certification, is needed that is expressed in terms of the concept of ROI, taking into account the expense involved in achieving LEED and Energy Star certification. (4) Buildings in the same sub-neighborhood and buildings in the overlap areas between the sub-neighborhoods of multiple certified buildings are assumed to experience the same impact due to the LEED and/or Energy Star certified office buildings in this study because it examines the impact of the certified office building on all the buildings in each sub-neighborhood rather than individual buildings. If the impact of a LEED and/or Energy Star certified office building were to be measured individually for a particular building in a sub-neighborhood, the sub-neighborhoods and the overlap areas would be distinguished to achieve the expected outcomes. (5) Only a very limited number of the office buildings achieved LEED Platinum certification for the whole building or any levels of LEED certification for only part of the building in this data of screened population, so confidence in the statistical results for both variables is inevitably constrained with regard to accepting the statistical significance of the results. The number of LEED Platinum certified office buildings and partial LEED certified office buildings should be increased by extending the study to additional comparable research areas or expanding the research period to achieve statistically significant results. In addition, the change of in the version of a building′s LEED certification over time was not considered in this research. (6) This study utilized the median unit market value for each sub-neighborhood rather than the individual unit market values of all the buildings in each sub-neighborhood because the objective here was to focus on the economic impact of a LEED and/or Energy Star certified office building on the sub-neighborhood as a whole instead of on the individual buildings in the sub-neighborhood. Therefore, future studies of the impact of a LEED and/or Energy Star certified office building on an individual building should utilize the individual unit market value of each building.

Conclusions

In the context of these limitations, these findings suggest that for the data set considered here, certification of LEED and/or Energy Star certified office buildings is indeed correlated with an increase in the median unit market values of buildings in their surrounding neighborhoods, and the strength of the impact of the unit market value of a LEED and/or Energy Star certified office building over time on the median unit market values for the surrounding sub-neighborhoods defined for this study clearly exhibit an inverse proportion pattern that demonstrates how the spillover effect of a LEED and/or Energy Star certified office building declines with decreasing proximity to the certified office building. As a result, the study revealed that LEED and/or Energy Star certification in the targeted geographic area, including the major characteristics of LEED certification, are correlated with positive economic benefits related to the unit market values of all the buildings located within 0.25 miles of the certified building, irrespective of their proximity to the LEED and/or Energy Star certified office building. In addition, the findings of this study suggest that LEED and/or Energy Star certified office buildings could play a role in encouraging mutual growth in the real estate market, thus satisfying part of the triple bottom line of sustainability for both LEED and Energy Star certifications. Therefore, this study should provide a useful foundation for further research to measure and confirm the spillover effect of LEED and/or Energy Star certified buildings from a socio-economic standpoint. The wider recognition of these positive economic effects is also likely to contribute to efforts to promote both the LEED and Energy Star certifications.

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References

Abelson, P. (1997). House and Land Prices in Sydney from 1931 to 1989. *Urban Studies*, 34, 1381–1400.

Aydin, R., Crawford, E., and Smith, B. A. (2010). Commercial Development Spillover Effects Upon Residential Values, Southwestern Economic Review, http://www.ser.tcu.edu/2010/SER2010-Aydin-et-al-47-62.pdf, (accessed August, 30, 2013).

Bloom, G. F., Weimer, A. M., Fisher, J. D. (1982). Real Estate, 8th Ed., John Wiley & Sons, New York.

Boyce, B. N. (1984). Real Estate Appraisal Terminology, Ballinger Publishing Company, Cambridge, MA.Chang, K., and Chou, P. (2010). Measuring the influence of the greening design of the building environment on the urban real estate market in

Taiwan, *Journal of Building and Environment*, 4S, 2057-2067.

Can, A. (1992). Specification and estimation of hedonic housing price models, *Journal of Regional Science and Urban Economics*, 22, 453-474.

Chang, K., and Chou, P. (2010). Measuring the influence of the greening design of the building environment on the urban real estate market in Taiwan, *Journal of Building and Environment*, 4S, 2057-2067.

Chun, B., Guldmann, J. M., and Seo, W. (2011). Impact of Multi-dimensional Isovist on Commercial Real Estate Values in CBD Area Using GIS, *Journal of Seoul Studies*, 12(3), 17-32.

Cypher, M. L., and Hansz, J. A. (2003). Does assessed value influence market value judgments? *Journal of Property Research*, 20(4), 305-318.

Dermisi, S. (2009). Effect of LEED Ratings and Levels on Office Property Assessed and Market Values, *Journal of Sustainable Real Estate*, 1(1), 23-47.

Dermisi, S., and McDonald, J. (2011). Effect of Green Designation on Prices/sf and Transaction Frequency: The Chicago Office Market. *Journal of Real Estate Portfolio Management*, 17(1), 39-52.

Dill, J. (2003) Transit use and proximity to rail – Results from large employment sites in the San Francisco, California, Bay Area. *Transportation Research Record* 1835: 19–24.

Drennan R. D. (2009). Statistics for Archaeologists: A Common Sense Approach 2nd Ed., Springer Science+Business Media, LLC., New York.

Dunse, N. and Jones, C. (1998). A hedonic price model of office rents, *Journal of Property Valuation and Investment*, 16(3), 297-312.

Eichholtz, P., Kok, N., and Quigley, J. M. (2010). Doing Well by Doing Good? Green Office Buildings, *American Economic Review*, 100(5), 2492-2509.

Epley, D. R., and Rabianski, J. (1981). Principles of real estate decisions, Addison-Wesley Publishing Company, Inc., Philippines.

Eply, D. R., Rabianski, J. S., and Haney, R. L. JR. (2002). Real Estate Decisions, Thomson Learning, Cincinnati, Ohio.

Ewing, R. (1995) Beyond density, mode choice, and single purpose trips. *Transportation Quarterly* 49(4): 15–24.

Federal Highway Administration. (2002) Toolbox for regional policy analysis, http://www.fhwa.dot.gov/planning/processes/tools/toolbox/, (accessed Nov 22, 2013).

Fisher, J. D., Geltner, D. M., and Webb, B. R. (1994). Value Indices of Commercial Real Estate: A Comparison of Index Construction Methods, *Journal of Real Estate Finance and Economics*, 9, 137-164.

Friedman, J. P., Harris, J. C., and Lindeman J. B. (2013). Dictionary of Real Estate Terms, Barron's Educational Series, Inc. Hauppauge, NY.

Fuerst, F., and McAllister, P. (2011). Green Noise or Green Value? Measuring the Effects of Environmental Certification on Office Values, *Journal of Real Estate Economics*, 39(1), 45-69.

Gelfand, A., Kim, H., and Sirmans, C. F. (1998). Spatio-Temporal Modeling of Residential Sales Data, *Journal of Real Estate Finance and Economics*, 23(1), 312-321.

Harris County Appraisal District (2009). Guide to understanding the property tax process. http://www.hcad.org/Help/Process/Guide.asp, (accessed November 2, 2013).

Haider, M. and Miller, J. E. (2007). Effects of Transportation Infrastructure and Location on Residential Real Estate Values: Application of Spatial Autoregressive Techniques, *Journal of the Transportation Research Board*, 1722(2000) 1-8.

Hinshaw, M. (2012). Urban walkability: the new driver in real estate values, http://crosscut.com/2012/05/29/real-estate/108851/hinshaw-public-spaces/, (accessed November 21, 2013).

Hough, D. E., and Kratz, C. G. (1983). Can "Good" Architecture Meet the Market Test?, *Journal of Urban Economics*, 14, 40-54.

Hui, E. C. M., Chau, C. K., and Law, M. Y. (2007). Measuring the neighboring and environmental effects on residential property value: Using spatial weighting matrix, *Journal of Building and Environment*, 42, 2333-2343.

Jeong, H. (2011). An Analysis on the factors affecting the capital value return – The case study of the office buildings in Seoul, Dissertation, Department of Real Estate, Chunju University.

Kanemoto, Y. (1997). Measurement of Development Benefits and the Hedonic Approach, Socioeconomic Evaluation of Road Investment Projects, 120-131, Keizai Inc, Tokyo, Japan.

Kang, K. and Kim, S. (2011). Analysis of the Elasticity of Loss Amount by Accident Types using Linear Mixed Effect Model, *Journal of Korea Insurance Research*, 22(1), 3-32.

Kerstens, S. M., De Ridder, R., Hof, A., Alberts, J., Mulhall, D., and Dale, D. (2011). Towards eco effective sustainable sanitation for the city of Almere, *Journal of Water Practice and Technology*, 6(2).

Kim, C., Phipps, T. T., and Anselin, L. (2003). Measuring the benefits of air quality improvement: a spatial hedonic approach, *Journal of Environmental Economics and Management* 45, 24–39.

Kim, K. and Son, J. (2011). Real Estate Economics, KU Smart Press, Seoul, South Korea.

Lee, J. (2010). Environmental economics, Pakyoungsa Publishing, Seoul, South Korea.

Lee, S., Lee, H., Son, J., and Choi, J. (2009). Developing Office Rent Model by Time-Series Analysis, *Journal of the Korea Real Estate Analysts Association*, 15(3), 5-17.

Leinberger, C. B. (2012). Now Coveted: A Walkable, Convenient Place. The New York Times http://www.nytimes.com/2012/05/27/opinion/sunday/now-coveted-a-walkable-convenient-place.html?_r=0, (accessed November 14, 2013).

Lin, Z., Rosenblatt. E.. and Yao, V. W. (2009). Spillover Effects of Foreclosures on Neighborhood Property Values, *Journal of Real Estate Finance and Economics*, 38(4), 387-407.

Liu, Y., Zheng, B., Turkstra, J., and Huang, L. (2010). A hedonic model comparison for residential land value analysis, *International Journal of Applied Earth Observation and Geoinformation*, 12(2), 181-193.

Mansfield, S., Pattanayak, S. K., McDow, W., McDonald, R., and Halpin, P. (2005). Shades of Green: Measuring the value of urban forests in the housing market, *Journal of Forest Economics*, 11, 177-199.

Matthews, J. W. (2006). The Effect of Proximity to Commercial Uses on Residential Prices, A Dissertation, Georgia State University and the Georgia Institute of Technology.

McGraw-Hill Construction (2008). Global Green Building Trends – Market Growth and Perspectives from Around the World, Smart Market Report: Design and construction intelligence, McGraw-Hill Construction, New York.

McGraw-Hill Construction. (2010). Green Outlook 2011 - Green Trends Driving Growth, McGraw-Hill, New York.

Miller, N., Spivey, J., and Florance, A. (2008). Does Green Pay Off?, *Journal of Real Estate Portfolio Management*, 14(4), 385-398.

Nelson, J. P. (1980). Airports and Property Values: A Survey of Recent Evidence, *Journal of Transport Economics and Policy*, 14(1), 37-52.

New York City Metropolitan Transportation Authority (2013), http://web.mta.info/nyct/facts/ffsubway.htm, (accessed October 23, 2013).

O'Donnell, P. T., and Maleady, E. L. (1975). Principles of Real Estate, Thomson Learning Publishing, Saunders, Philadelphia.

O'Sullivan, A. (2009). Urban Economics 7th Ed., McGraw-Hill Companies, Inc., New York.

Oklahoma City Embark (2013). www.gometro.org/benefits, (accessed October 24, 2014).

Pollakowski O. H. and Wachter, M. S. (1990). The Effects of Land-Use Constraints on Housing Prices, *Land Economics*, 66(3), 315-324.

Reichert, A. K. (2002). Hedonic Modeling in Real Estate Appraisal: The case of Environmental Damages Assessment, Real Estate Valuation Theory, Kluwer Academic, Boston.

Retsinas P. N. and Belsky, S. E. (2002). *Low-Income Homeownership: Examining the unexamined goal*, The Brooking Institution, Washington, D.C.

Rood, T. (2000). Ped Sheds. San Francisco, CA: Congress of the New Urbanism.

Saphores, J., and Li, W. (2012). Estimating the value of urban green areas: A hedonic pricing analysis of the single family housing market in Los Angeles, CA, *Journal of Landscape and Urban Planning* 104, 373-387.

Seltman H. J. (2014) Experimental Design and Analysis, Chapter 15 Mixed Model, 357-378, http://www.stat.cmu.edu/~hseltman/309/Book/chapter15.pdf, (accessed March 24, 2014).

Sohn, D. W., Moudon, A. V., and Lee, J. (2012). The economic value of walkable neighborhoods, *Urban Design International*, 17(2), 115-128.

Song, K. (1999). The Study of Random Effects in Linear Mixed Model for the Analysis of Repeated Measures, Dissertation, Yonsei University, South Korea.

Spreckley, F. (1981). Social Audit: A Management Tool for Co-operative Working 1981, Beechwood College Ltd., Leeds, United Kingdom.

SPSS Inc. (2005). Linear Mixed-Effects Modeling in SPSS: An Introduction to the MIXED Procedure, Technical Report LMEMWP-0305.

Starkweather, J. (2010). Linear Mixed Effects Modeling using R, http://www.unt.edu/rss/class/Jon/Benchmarks/LinearMixedModels_JDS_Dec2010.pdf, (accessed March 23, 2014).

Suh, M., Pearce, A. R., and Kwak, Y. (2013). The effect of LEED certified building on the neighborhood market value in New York City, The 5th International Conference on Construction Engineering and Project Management, Jan 9-11, Anaheim, CA, USA.

Suh, M., Pearce, A. R., Song, Y., Kwak, Y., and Zhang, Y. (2015). The Impact of LEED-Energy Star Certified Office Building on the Market Value of Adjoining Building in New York City, *Under reviewing for Journal of Sustainable Real Estate.*

Tandon, S. (2012). Measuring Spillover Effects of Residential Amenity Improvements Using Spatial Hedonic Approach, Dissertation, University of Nevada, Las Vegas, NV.

The City of New York (2014). PlaNYC website: http://www.nyc.gov/html/planyc/html/about/about.shtml, (accessed November 31, 2013).

Warren A., Kramer, A., Blank, S., and Shari, M. (2013). Emerging Trends in Real Estate 2014, PwC and the Urban Land Institute, Washington, D.C.

Weinberger, R. R. (2001). Commercial property value and proximity to light rail: A Hedonic Price Application. Dissertation, University of California Berkeley, CA.

West B. T., Welch, K. B., and Galecki, A. (2007). Linear Mixed Models: A Practical Guide Using Statistical Software, Taylor & Francis Group, Boca Raton, FL.

Wiley, J. A., Benefield J. A., and Johnson K. H. (2010). Green Design and the Market for Commercial Office Space. *Journal of Real Estate Finance & Economics*, 41(2), 228–243.

Zhang, Y. (2010). Residential Housing Choice in a Multihazard Environment: Implications for Natural Hazards Mitigation and Community Environmental Justice, *Journal of Planning Education and Research*, 30(2), 117-131.

CHAPTER 6

Conclusions and Recommendations

Summary

This dissertation aimed to shed new light on the role of LEED and/or Energy Star certified office buildings and the economic benefits they bring to their neighboring buildings, thus satisfying part of the sustainability goals for LEED and Energy Star certification from an economic standpoint through encouraging mutually beneficial growth in the property values of the certified office buildings and other buildings in their neighborhoods or local communities, as a win-win approach. According to the purpose of this research, this research explored the spillover effect due to a LEED and/or Energy Star certified office building on buildings in the surrounding neighborhood in Manhattan, New York City during the period 2007-2013, using both geographical and statistical approaches. Building on the definition of “neighborhood”; the effect first on adjoining buildings, then on a simple neighborhood within a 0.25 mile “walkable distance” was examined. Finally, the spillover effects on a series of neighborhoods at steadily decreasing proximity to the certified building were modeled, with proximity defined by drawing five concentric doughnuts at intervals of 0.05 miles (0-0.05 miles, 0.05-0.1 miles, 0.1-0.15 miles, 0.15-0.2 miles, and 0.2-0.25 miles). The market values estimated by NYC’s DOF were utilized as a reasonable representation of the property values for buildings in the data set, and the GIS data recently released by the NYC’s DCP was used to match each building’s BBL numbers for the two different types of data through ArcGIS 10.1. The hedonic price model and the linear mixed effect model were applied in this research to examine the correlation between LEED and/or Energy Star certified office buildings and buildings in their neighborhood, as well as the correlation between their certification attributes and buildings in their neighborhood and sub-neighborhood, from an economic standpoint based on the unit market values of the certified buildings and median unit market value of their neighbors and sub-neighbors using the R-Project 3.0.2 statistical software package.

Findings

Based on the statistical results of this research, the major findings include the following for the data set studied in this research:

- LEED and/or Energy Star certified office buildings were significantly associated with the unit market value of adjoining buildings, and the achievement of certifications had a positive impact on the unit market value of nearby buildings. Moreover, the Certified or Silver level of LEED and LEED certification of the entire building both had a positive economic impact on adjoining buildings in this data set. However, the LEED Platinum level appeared to have a negative effect on adjoining buildings, and the LEED Gold level and LEED certification for projects in which only part of the building was certified were found to have an insignificant influence on the market values of adjoining buildings in this research.

- Overall, for the buildings studied in this research, the unit market value of a LEED and/or Energy Star certified office building was found to have a positive economic impact on the median unit market value of its neighborhood, defined as the area within the 0.25 mile “walkable distance” from the certified office building, and the achievement of LEED and/or Energy Star certification also had a positive impact on neighborhood’s median unit market values. Specifically, LEED certification appeared to have a stronger impact on the neighborhood’s median unit market value than Energy Star certification for this set of buildings, and both LEED certification coverages (for part of a building and for a whole building) and all LEED certification levels except the LEED Platinum level were found to be significantly positively correlated with the median unit market values of buildings in the neighborhood.

- In general, correlations were found in this data set between the median unit market value of each sub-neighborhood surrounding a LEED and/or Energy Star certified office building and proximity to the certified office building. Most of the features of LEED certification and the achievement of LEED or Energy Star certification were also significantly correlated with the median unit market value of each sub-neighborhood from an economic standpoint, although no specific patterns were detected with respect to strength of effect vs. proximity for specific attributes of the certification systems. In contrast, the strength of the spillover effect on incremental unit market value of a LEED and/or Energy Star certified office building was shown to be inversely proportional to a building's proximity to the certified building, which agrees with previous findings in the literature. However, the remaining independent variables, LEED certification coverages and LEED certification levels, presented non-systematic patterns in their coefficients for each sub-neighborhood within the 0.25 mile radius of the certified building based on their decreasing proximity to the LEED and/or Energy Star certified office building during the period covered by this research, 2007 – 2013.

Conclusions

The research reported here collectively investigated the impact of LEED and/or Energy Star certified office buildings on buildings located within their neighborhood boundaries depending on their proximity to a LEED and/or Energy Star certified office building in Manhattan, NYC during the period 2007-2013. The findings of these studies demonstrate the potential economic impact of a LEED and/or Energy Star certified office building on adjoining buildings, as well as on other buildings within specific radius neighborhood and sub-neighborhood boundaries. These research findings suggest that the spillover effect might depend on the two significant characteristics of the LEED and/or Energy Star certified office buildings themselves, namely the levels and coverage of LEED certification. Moreover, these characteristics of the certified office building were correlated with different impacts on the unit market values of adjoining buildings and the median unit market value of buildings in the neighborhood and sub-neighborhood. Based on the statistical analysis results, the higher levels of LEED certification provided a stronger economic impact on their median unit market value of neighborhood and sub-neighborhood, as described in Chapters 4 and 5. In particular, the median unit market value of buildings in the neighborhood and sub-neighborhood served as a good indicator when measuring variations in the market value of buildings in a specific neighborhood. The median unit market value, as one of the real estate market measurements for a particular area, was also found to be an appropriate way to reveal increases in the impact of unit market value of a LEED and/or Energy Star certified office building on the median unit market value of buildings in each sub-neighborhood with decreasing proximity to the certified office building as explained in Chapter 5, which analyzed the spillover effect of a LEED and/or Energy Star certified office building. These results confirm that LEED and/or Energy Star certified office buildings could play a role as a beneficial external environmental feature in the existing environment; moreover, they also indicate that certified office buildings also support mutual growth in local real estate markets from an economic standpoint.

Contributions

This research provided a comprehensive analysis of the spillover effect of LEED and/or Energy Star certified office buildings on buildings in their neighborhood in Manhattan, NYC during the period 2007-2013, and the strength of spillover effect due to a certified office building was shown in this data set to depend on the proximity to that certified building. This demonstrates that an office building that has achieved LEED and/ Energy Star certifications may generate property economic benefits not only for the certified office building itself but also for the buildings in its neighborhood. The identification of these property economic benefits provides further support for our current understanding of the economic benefits of LEED and/or Energy Star certified office buildings by quantifying the spillover effect of a LEED and/or Energy Star certified office building on other buildings in its neighborhood as a win-win situation. Furthermore, the findings of this study represent fundamental research that lends support for the benefits gained as a result of the widespread diffusion of LEED and/or Energy Star certification to the local community and the growing awareness of the benefits of these certifications by local policy-makers, highlighting their stimulation of the local real estate market and the support it provides for efforts to achieve a part of the sustainability for LEED and Energy Star certifications. Although the findings provide limited evidence supporting the spillover effects of LEED and/or Energy Star certified office buildings on their neighborhoods within a walkable distance, future research to develop a prediction model for these spillover effects could be helpful for local policy makers. In addition, the geographic and statistical approach methodologies can be useful to comprehend the role of both LEED and Energy Star certifications in the construction and real estate industries with an economic standpoint for another metropolitan area in the U.S.

Recommendations for Future Research

This research was subject to several limitations in addressing the research questions as follows: (1) the selection of a particular geographical research area, Manhattan NYC, and a limited research period, from 2007 through 2013, the limited number of LEED and/or Energy Star certified office buildings with two major specific characteristics of LEED certification, LEED certification levels and coverages, due to the limited screened population frame, and a focus on a single, very specific, type of LEED and/or Energy Star certified property (offices) instead of all types of property; (2) the assumption that the impact of a national economic recession such as the one suffered in the U.S. subprime mortgage crisis in 2007 will have an equivalent effect on the overall natural real estate market trends in Manhattan NYC over time; (3) the direct or indirect effect of human perceptions of LEED and/or Energy Star certification in the real estate market were not considered; (4) market values of properties provided by government agencies were utilized instead of actual transaction or sales prices; (5) differences in the way energy performance is assessed for LEED certification and Energy Star certification were excluded; (7), the current research focused on the use of an estimating model for the spillover effect due to LEED and/or Energy Star certified office buildings, and (8) excluding the multiple impacts of LEED and/or Energy Star certified office buildings on the unit market value of adjoining buildings or the median unit market value of buildings in their neighborhoods and conducting the one-on-one correlation between a LEED and/or Energy Star certified office building and an adjoining building or a building in the neighborhood through a statistical analysis approach. Given these limitations, the study findings are limited and only restricted conclusions can be drawn in this dissertation.

Future research based on the findings of this dissertation related to the spillover effects of LEED and/or Energy Star certified office buildings should therefore include the following: (1) expand the screened population group frame to enhance the statistical significance by covering multiple research locations and a longer research period, as well as heterogeneous environmental features in the existing environment, and an integrated and improved equivalent database containing in-depth information on LEED and Energy Star certifications including changes in the version of LEED certification over time as well as economic and geographic information; (2) consider the impact of a national or regional economic recession on the natural real estate market, especially the property value of buildings in a specific area individually over time; (3) examine the precise reasons for the major fluctuations in the renewal and withdrawal of Energy Star certification, including the perceptions of developers that may be driving the growth in the number of investments and developments and the diffusion of both certifications, directly or indirectly, during the research period; (4) compare data on actual transaction and sales prices with the market value data, including an examination of the concept of ROI that compares the financial expense incurred in achieving LEED and Energy Star certification invested by the building owners, investors, or developers with the economic benefits gained as a result of achieving the certification to reveal the potential impact of the findings reported here; (5) compare any differences due to the economic impact of LEED certification, which is based on the prediction of energy performance, and Energy Star certification, which is based on actual energy consumption, on the market values of the certified buildings and those of other buildings in their surrounding neighborhoods; and (6) develop prediction models for the spillover effect due to LEED and/or Energy Star certified buildings based on the numerical confirmation models in this dissertation by adding the required features of subjective buildings. (7) It could also be a useful future research direction to develop a numerical model to predict the overall economic impact of LEED and Energy Star certifications on individual neighborhoods due to the spillover effect, which is directly related to proximity to the certified office building. The research conducted for this dissertation, which focuses on the correlation between the presences of a LEED and/or Energy Star certified office building and neighborhood market values, will serve as the first step towards developing a new model which can be a useful method to predict the economic benefits for developers, investors and owners from a ROI or Internal Rate of Return (IRR) viewpoint during their decision making process through forecasting the spillover effect of a LEED and/or Energy Star certified building. Furthermore, this research can be expanded to include aspects of the socio-economic domain because the property values of buildings achieving LEED and/or Energy Star certification in the construction and real estate domains are likely to be directly or indirectly connected to numerous socio-economic factors.

Appendix A

Glossary

No.	Terminology	Definition (in Dissertation)
1	Building amenities	Building features that generate both tangible and intangible benefits and bring satisfaction to owners and users.
1.1	Building area	The number of square feet in the building. Used to calculate floor-area-ratio (FAR) in conjunction with the lot area.
1.2	Building floors	The number of stories a building has
1.3	Floor-area-ratio (FAR)	The ratio of the building area to the lot area (ft^2). FAR may be an important factor when estimating property values. ***Formula: Floor-area-ratio = Building area / Land area***
1.4	Year built	The year a building was first assessed for property taxes by the governing body.
1.5	Year renovated	The year work was completed to improve and upgrade an existing building without changing its original appearance or structure in order to achieve green building certification. (Renovation, Remodeling, and Rehabilitation)
1.6	Zoning	Used by city governments to regulate building size and use, population density, and the way land is used. A city's changing demographic and economic conditions can be demonstrated by zoning as it is a key tool for carrying out planning policy.
1.6.1	Zoning lot	A tract of land that consists of more than one tax lot within a block. The zoning lot is a basic unit for zoning regulation.
1.6.2	Corner lot	A zoning lot that adjoins the point of intersection of two or more streets.
1.6.3	Interior lot	A zoning lot that is located between any types of lots and adjoins only one street.
1.6.4	Through lot	A zoning lot that is not located at the corner of block and generally links two parallel streets.
2	Values	The quantity of one thing that can be expressed and exchanged for another; Money is commonly used for measuring property values.
2.1	Assessed value	The assessed value is used to calculate the property tax using a specific equation such as the following: *Assessed Value = Market Value × Level of Assessment*. It is divided into two different assessed values: Actual assessed value and Transitional assessed value. The Assessed Value of Classes 1, 2a, 2b and 2c is modified by caps on assessment increases.
2.3	Market value	Generally the sale price of property under normal conditions. The Department of Taxation and Finance of New York State recommends the use of a sales comparison approach for estimating real estate market values. NYC's Department of Finance estimates the worth of property in order to estimate the property's tax class and to meet New York State's legal requirements. The market value is the starting point for calculating the taxable value of a property, and one of three approaches is used: (1) the comparable sales approach, (2) the income and expenses approach, or (3) the cost, or summation, approach. Annual data for income and expenses and recent sale prices of comparable properties are applied to statistical models for 4 classes of building.

2.4	Unit market value	The unit market value is calculated by market value and rentable building area (RBA), and it is expressed in 'dollars/sq-ft'.
2.3.1	Comparable sales approach	An approach to valuation based on recent sales prices of comparable properties that have been sold in a similar neighborhood and condition. Comparable properties will also have similar physical characteristics such as building size, ages, lot size, etc. This approach is applied to Class 1 buildings by NYC's Department of Finance.
2.3.2	Income and expense approach	An approach to valuation that uses two available techniques: the estimated future Net Operation Income (NOI) of the property and a Capitalization Rate, which consists of the Gross Income in relation to the property value and multiplier. Both techniques are based on data related to the annual Real Property Income and Expense (RPIE) and used to estimate market value. This approach is applied to buildings in Tax Class 2 or Tax Class 4 by NYC's Department of Finance (DOF).
2.3.3	Cost or summation approach	An approach to valuation in which property value is generally determined by the land value plus the building reproduction or replacement costs, minus depreciation. This approach is applied for Tax Class 3 buildings by NYC's Department of Finance (DOF).
2.4	Occupancy rate	The current percentage of rented units in a building, the converse of the vacancy rate.
2.5	Rental value	The periodic rent charged per property (unit, floor, or building) for using space. In general, the rental rates are determined by the principle of appraisal analysis.
2.6	Resale value	The assumed selling price if the property were to be resold.
2.7	Sales price	The amount of money required to acquire the ownership of a particular property; the actual selling price for transferring the ownership of a particular property.
3	Environmental	Everything outside of the attributes of the property or building itself (tangible or intangible) that could affect any aspect of a property, including economic, social, political, and physical factors.
3.1	External environmental features	All characteristics of the area surrounding a property that could have an effect on its property value, either directly or indirectly.
3.1.1	Adjoining street	A street sharing a common side zoning lot line with a building (touching; attaching; contiguous; abutting)
3.1.2	Distance	The straight-line separation between buildings or physical targets.
3.1.3	Proximity	The closeness in time or space between two objects, in this case a LEED and/or Energy Star certified building and a comparable building in the neighborhood within 0.25 mile.
3.1.4	Walking distance	A distance considered comfortable by commuters for walking to their target, commonly, 1/4 to 1/2 mile or 5 to 10 minutes at an average walking pace. This research takes 1/4 (0.25) mile to be the walking distance and this is used as the criterion defining a neighborhood area (radius).
3.2	Environmental performance	The relationship between the building and the environment, including the environmental effects of the resources consumed over the building's entire life cycle.
3.3	Environmental quality	The degree of contamination of the natural environment due to human activities during the building's life cycle.

4	Green building certification	A formal acknowledgement of a building's environmental performance based on a standard, systematic evaluation protocol. This research focuses specifically on either of two green building certifications (LEED and Energy Star) commonly used in the US to demonstrate the environmental performance of a building.
4.1	Certified	Having met the official requirements of LEED or Energy Star certification to achieve certification, receiving official approval to be designated a LEED or Energy Star certified building.
4.2	Rated	To place in a particular rank or grade or to be ranked in a particular class.
4.3	Registered	Having submitted basic project documentation and paid a fee to be officially listed by an organization as having the intent to pursue certification.
4.4	Levels	LEED requires a minimum number of points or credits to achieve a base level of certification, with higher levels of certification available based on further accumulation of points or credits. No levels are assessed for Energy Star certification.
4.5	LEED coverage	The portion or area of a property covered by a LEED certification. Various types of LEED certifications exist, and each LEED certification may cover a different portion of office building, a whole office building or a part of office building; • LEED covers a whole building (LEED fully): New construction and major renovation; Existing buildings operations and maintenance; Core and shell development • LEED covers a part of building (LEED partially): Commercial interiors[25]
5	Land use planning	The act of determining limitations for functional use of a particular parcel of land within a government's jurisdiction. Land use in New York City is categorized in terms of 10 different types of function.
5.1	1&2 Family Residential	Buildings used as residences by no more than one or two families. In NYC, low-density residences, the largest use of city land, are found mostly in Staten Island, eastern Queens, southern Brooklyn, and northwest and eastern areas of the Bronx.
5.2	Commercial	Buildings used for retail activities. These uses occupy only a relatively small fraction of the city's land (~4 percent), but they use space intensively. Most of the city's 3.7million jobs are in commercial areas, ranging from the office towers of Manhattan and the regional business districts of downtown Brooklyn, Long Island City, Jamaica, and the Hub, to local shopping corridors throughout the city.
5.2.1	Office building	Any type of building primarily used for business.
5.3	Industrial	Buildings used for manufacturing, storage, or service of manufactured goods. Industrial uses such as warehouses and factories occupy another 4 percent of the city's total lot area are found primarily in the South Bronx, on either side of Newtown Creek in Brooklyn and Queens, and on the northern and western shores of the Brooklyn and Staten Island waterfronts.

[25] http://www.usgbc.org/leed/certification/guidance/construction-type (accessed on Nov 29, 2013)

5.4	Public Facilities & Institutions	Buildings owned by governments or other organizations that serve the public, including schools, hospitals and nursing homes, museums and performance centers, houses of worship, police stations and fire houses, courts and detention centers.
5.5	Mixed use	Buildings containing more than one distinct use. This is most often typified by apartment buildings with stores and/or neighborhood services on the ground level. Mixed use buildings containing offices and residences are also included in this category, but are less common.
5.6	Multi-family residential	Buildings used as residences by three or more family units. Medium- to high-density residential buildings (three or more dwelling units) contain more than two-thirds of the city's housing units but occupy approximately 12 percent of the city's total lot area. The highest density residences are found mainly in Manhattan, but four- to twelve-story apartment houses are common in many parts of the Bronx, Brooklyn and Queens.
5.7	Open space & outdoor recreation	Properties for entertainment or public use that have only incidental buildings and are mostly open space. 10 percent of the city's lot area is occupied by public parks, playgrounds and nature preserves, cemeteries, amusement areas, beaches, stadiums and golf courses.
5.8	Parking	Properties used for the parking of motor vehicles. Includes public and private off-street lots and free-standing garages that are not an accessory to residential or commercial buildings.
5.9	Transportation / Utilities	Properties required for the provision of infrastructure services. Airports, ferry terminals, train yards, sewage treatment facilities and power plants are among the city's essential infrastructure uses.
5.10	Vacant lots	Land that is not currently being used or not developed and/or improved.
6	Neighborhood	A district or locality characterized by similar or compatible land uses and homogenous groupings. Neighborhood boundaries consist of well-defined natural or man-made barriers, land use changes or the characters of the inhabitants. For this research, the radius of the neighborhood of each LEED and/or Energy Star certified building is taken to be 1/4 (0.25) of a mile based on a comfortable walking distance. The neighborhood area is divided into 5 sub-neighborhood areas by each 0.05 mile from the LEED and/or Energy Star certified building (a radius of: 0.05 miles, 0.1 miles, 0.15 miles, 0.2 miles, and 0.25 miles).
6.1	Non-certified building	A building that has not achieved at least one of two certifications, LEED or Energy Star, and is located in the neighborhood of a LEED and/or Energy Star certified building.
6.2	Adjoining non-certified building	A property that has not achieved at least one of two certifications under similar external environmental conditions and shares a common side zoning lot line with a LEED and/or Energy Star certified building.
6.3	Comparable building	A property with similar characteristics that could be used as a counterpart to compare economic values with a LEED and/or Energy Star certified building due to common external environmental features that impact on the buildings' property values.
7	New York City	New York City is located in the State of New York. It is composed of 5 boroughs (Manhattan, Brooklyn, the Bronx, Queens, and Staten Island), which were consolidated in a single city in 1898. The city has 59 community districts and a population of more than 8 million inhabitants.

7.1	Borough	One of the 5 constituent political divisions of New York City: Manhattan, Brooklyn, the Bronx, Queens, and Staten Island.
7.2	Block	A tract of land bounded on all sides by streets or a combination of streets, public parks, railroad rights-of-way, pier headlines or airport boundaries.
7.3	Lot /Zoning lot	A tract of land comprising a single tax lot or two or more adjacent tax lots within a block. The zoning lot is the basic unit for zoning regulations and may be subdivided into two or more zoning lots. Two or more adjoining zoning lots on the same block may be merged provided that all resulting zoning lots comply with applicable regulations. There are 3 types of zoning lots: corner lots, interior lots, and through lots.
8	Real estate market	The potential buyers and sellers of property at a particular time, and the current transaction activity related to property. This is a commercial activity designed to facilitate the exchange of ownership in realty. The real estate market here refers to the real estate market in New York City.
8.1	Heterogeneous market	In the real estate market, an area or neighborhood composed of various types of property uses and/or occupants of dissimilar cultural, social, or economic backgrounds.
9	Sustainable	A process or artifact that can be continued indefinitely. To be classed as sustainable, this should give equal weight to include social, economic, and environmental aspects.
9.1	Green	A process or artifact that provides environmental benefits and healthy lifestyles for human society.
10	Tax class	A classification of property based on how much property tax it must pay. Property in NYC is divided into 4 classes from Class 1 to 4 based on the purpose of the building.
10.1	Class 1	Most residential property of up to three units (family homes and small stores or offices with one or two apartments attached), and most condominiums that are not more than three stories in height.
10.2	Class 2	All other property that is not in Class 1 and is primarily residential (rentals, cooperatives and condominiums). Class 2 includes: - Sub-Class 2a (4 – 6 unit rental buildings) - Sub-Class 2b (7 – 10 unit rental buildings) - Sub-Class 2c (2 – 10 unit cooperatives or condominiums) - Class 2 (11 units or more).
10.3	Class 3	Most utility property.
10.4	Class 4	All commercial and industrial properties, such as office, retail, factory buildings and all other properties that are not included in tax classes 1, 2 or 3.
11	Building Class	A subjective quality rating of buildings that indicates the competitive ability of each building to attract similar tenants or users. It is based on both metropolitan and internal factors within an office space market, specifically building factors such as rent, building finishes, system standards and efficiency, building amenities, location/accessibility, and market perceptions.

11.1	Class A	In general, a class A building is an extremely desirable investment-grade property with the highest quality construction and workmanship, materials and systems, significant architectural features, the highest quality/expensive finish and trim, abundant amenities, and first rate maintenance and management. It is usually occupied by prestigious tenants paying above average rental rates and is in an excellent location, with exceptional accessibility. These buildings are most eagerly sought by international and national investors willing to pay a premium for quality and are often designed by architects whose names are immediately recognizable. A building meeting this criteria is often considered to be a landmark, either historical, architectural or both. It may have been built within the last 5-10 years, but if it is older, it will have been renovated to maintain its status and provide it with extra amenities. Buildings of this stature can be one-of-a-kind with unique shape and floor plans, notable architectural design, excellent and possibly outstanding location and a definite market presence.
11.2	Class B	In general, a class B building offers more utilitarian space without special attractions. It will typically have ordinary architectural design and structural features, with average interior finish, systems, and floor plans, and adequate systems and overall condition. It will typically not have the abundant amenities and location that a class Abuilding will have. This is generally considered to be more of a speculative investment. The maintenance, management and tenants are average to good, although Class B buildings are less appealing to tenants and may be deficient in a number of respects including floor plans, condition and facilities. They therefore attract a wide range of users with average rents. They lack prestige and must depend chiefly on their lower price to attract tenants and investors. Typical investors may be national but are mostly local.
11.3	Class C	In general, a class C building is a no-frills, older building that offers basic space. The property has below-average maintenance and management, a mixed or low tenant prestige, and inferior elevators and mechanical/electrical systems. As with Class B buildings, they lack prestige and must depend chiefly on lower prices to attract tenants and investors.
11.4	Class F	A functionally or economically obsolete building that does not offer a viable alternative for space and does not "compete" with others of similar type for occupancy by businesses seeking a location for operations. These buildings will usually have externally visible physical or structural features as well as internal ones that render it undesirable and is therefore not competitive with any other properties in the market. The property may even be tagged as "Condemned" by the local authorities
12	Flood Hazard Area	The areas that have more than 1 percent chance of being inundated by a flood each year. This area is decided as a part of the 100-year-plain. Three distinct types of flooding in NYC; coastal flooding, river flooding, and flash flooding.
12.1	Zone Z	This zone potentially suffers from high velocity wave action, including 3-foot breaking waves from a 1 percent annual chance coastal flood. The building requirements of Zone Z are stricter than those of other zones due to the higher level of risk.
12.2	Zone A	This zone has the potential for storm surge flooding from a 1 percent annual chance coastal flood. This zone is not likely to be subject to high velocity wave action, but is still considered at high risk of flooding.
12.3	Shaded Zone X	This zone has a moderate coastal flood risk, with less than 0.2% annual chance flood level.

Appendix B
Extended Literature Review

Background

Building performance by green features of green certification and property economic benefits.

Green building certifications, which are also often referred to as green building certification systems, have been developed by a number of organizations in the United States and elsewhere in the world since the concept was first introduced at the beginning of the 1990s. The objectives and frameworks of the various green building certification schemes are designed to accomplish specific building performance objectives and to evaluate the overall building performance with regard to minimizing negative environmental impacts through reducing energy use, water consumption, pollution, and material inputs and improving indoor air quality and occupant satisfaction (The Secretariat of the Commission for Environmental Cooperation 2008).

This research focused on the two certification programs most widely used in the United States: LEED and Energy Star. We would expect the property values of LEED and/or Energy Star certified buildings to be related to building performance because the certifications reward building designs that are more efficient, leading to building users or tenants expecting a number of financial benefits from this efficiency during the building operation and maintenance phases (von Neida & Hicks 2002; Kats et al. 2003; USEPA 2004; 2006; 2013). To determine whether these expectations of tenants and building users are justified, multiple researchers have studied the building performance of LEED and/or Energy Star certified buildings. Booz Allen Hamilton (2008) reported that LEED certification did indeed lead to reductions in energy use, saving owners of LEED certified buildings in the United States about $281 million from 2000 to 2008. They estimated that certification had the potential to save a further $4.8 billion from 2009 to 2013 due to reduced energy consumption. Simultaneously, CO_2 emissions were reduced by approximately 2 million metric tons in the period from 2000 to 2008, with a predicted dramatic decrease of a further 34 million metric tons from 2009 to 2013. The Communication Department of the CEC Secretariat (2008) noted that LEED certified buildings reduced energy use by 30 percent, carbon emissions by 35 percent, and water consumption by 30 to 50 percent, as well as generating waste cost savings of 50 to 90 percent. LEED certified buildings could also provide new opportunities to foster stronger communities and support significant improvements in both human health and productivity. Studies by Roe et al. (2001), USDOE (2008), and Kok et al. (2011) all described how LEED certification looked forward to cover not only the building's energy efficiency performance, but also its sustainability performance by including human and environmental health, which might provide even more value in areas where incomes were higher. In addition, Energy Star certification pursued energy efficiency in building operations. Von Neida and Hicks (2002), Kats et al. (2003), and USEPA (2004; 2006; 2013) found the following financial benefits of Energy Star certified office buildings:

■ Direct energy savings:
- One-third more energy efficient than average U.S. office buildings
- At least $0.50 per sq-ft savings on annual energy bills in 2006
- Cash flow improved by $0.95 for every $1 per square foot savings in office building energy costs in 2013
- 35 percent lower energy bills than the average energy bill of buildings
- Reduction of exposure to volatile energy and fuel prices

■ Persistence of energy performance and savings
- Energy savings in the first year after becoming Energy Star certified
- 20 percent more energy efficient in the sixth consecutive year compared to the first year of certification

■ Higher occupancy rates
- High satisfaction of tenants and users using the usage of Energy Management and Control Systems by the occupancy
- Higher occupancy rates in Energy Star certified buildings

■ Improved property values
- Higher net operating income from energy cost savings and lower operations and

maintenance costs

- Higher economic building valuations (rental rates: +6.5/selling prices: +12.9 percent)

■ Additional benefits

- Lower CO_2 emissions
- Reduction and mitigation of the risk of new utility pricing schemes, including peak electricity price, demand charges, and tiered rate structure savings

In comparison to these financial benefits, Scofield (2009) concluded that small LEED certified office buildings consumed less energy based on the results of the Commercial Building Energy Consumption Survey (CBECS) and the majority of LEED certified office buildings used less energy than comparable non-LEED certified office buildings from a statistical standpoint, although relatively large certified office buildings still consumed more energy than their non-LEED certification counterparts. This suggested that it should not automatically be concluded that LEED office buildings had a better energy performance than conventional office buildings; other characteristics of LEED certified office buildings must also be taken into account.

LEED and/or Energy Star certification recommends several specific green features such as bicycle racks, photovoltaics, etc., and Table B. 1 provides details of several green features for green buildings. These could be related to the green building certifications for new office building construction through the adoption of a broad combination of specific features and technologies (Muldavin 2010).

Table B. 1. The adoption of green features for green buildings

Green building areas	Description of green features
Sustainable Sites	- Optimal daylight exposure through building orientation - Reflective roof surface to reduce heat island effect - Brownfield or urban in-fill location - Habitat restoration or open space preservation - Bicycle and carpool parking - Light pollution reduction - Storm water management/treatment - Pedestrian and bike connections - Enhancement of the existing environment - District development
Water Efficiency	- Water-efficient landscaping (native/drought-tolerant landscapes) - Low-flow lavatory toilets and faucets - Storm water retention systems for landscape irrigation
Energy and Atmosphere	- High efficiency HVAC system - High efficiency interior lighting with daylight dimming and occupancy or vacancy sensors - High performance window glazing - Photovoltaic or other on-site renewable energy - Additional insulation - Commissioning of HVAC and other systems - Optimization of size opening, window glazing, utilizes shading devices, etc.)
Materials and Resources	- Environmentally friendly construction materials (local, renewable, reusable, certified, etc.) - Waste management plan for diverting construction debris - Improvement of awareness of opportunities for salvage, reuse, and recycling
Indoor Environmental Quality	- Low VOC-emitting materials (paints, flooring, and carpet adhesives) - Daylighting and exterior window views - Zoned heating and cooling - Under-floor ventilation - Operable windows - Air intakes positioned away from pollution sources - Enclosed, ventilated mechanical rooms - CO_2 sensors - Moisture control for preventing microbial contamination
Innovation and Design Process	- Integrated design and construction approach - Expanded design team including energy modeler, solar design expert, and commissioning agent

Several green features from Table B. 1 could have multiple impacts on the decision making process, including the evaluation of property values for buying or leasing a building, due to a number of reasons; for instance, effective daylight systems and ventilation systems increase employee productivity, improve their health, and reduce the building's operational costs. Consequently, several researchers have attempted to evaluate the valuation of green buildings by utilizing the outcomes caused by green features such as energy and water use or the consumption of natural resources (Ries et al. 2006; Popescu et al. 2009; Yu et al 2011; Sanderford 2013). However, although the contributions of some of these green features could be felt by decision makers and property value appraisers, it was difficult to argue that the specific green features recommended achieving LEED and/or Energy Star certification had a direct impact on increasing the real estate market value of LEED and/or Energy Star certified office buildings. For example, although some green features were very helpful for achieving LEED and Energy Star certifications, there has been shown to be a small direct positive effect on the property cash flow as a result of providing bike racks near a building or enhancing existing environments (Muldavin 2010). Additionally, many of these green features or technologies cost more than traditional construction features or technologies through the requirement to use certified materials, which were generally more expensive than traditional materials (Muldavin 2010). Yu et al. (2011) have argued that further research into the relationship between green buildings and capital value was needed to test these issues, and Lützkendorf and Lorenz (2005) concluded that the awareness of sustainability was very limited in most property professionals. One of multiple studies that have disagreed with these contentions, however, concluding that the construction cost involved in achieving sustainable design could remain within the initial green building budget. There were clearly still conflicting conclusions regarding the relative construction costs of green building and non-green traditional building (Kats et al. 2003).

When NYC's Department of Finance estimated the real estate market value of all the properties in the city, they did not take into account any financial benefits that might accrue to a LEED and/or Energy Star certified building, nor did they provide any tax benefits to the certified buildings. The DOF did not consider every green feature or green technology which was applied to a LEED and/or Energy Star certified building (Mayor's Office of Long-Term Planning and Sustainability 2012). However, when they calculated the property tax for Tax Class 2, they did allow abatement for two particular green features when calculating property tax: solar panels and a green roof (NYC Finance 2013). Both these green features were considered in terms of their impact on building performance, although only solar energy through solar panels was included in the Energy Star certification as an evaluation factor. In general, the NYC government did not currently consider either green building certification, whether LEED certification or Energy Star certification, or any green building features or technologies that were related to only the tax value when estimating property market value.

References

Booz Allen Hamilton (2008). Green Jobs Study, http://www.usgbc.org/ShowFile.aspx?DocumentID=6435, (assessed March. 10, 2012).

Department of Project Management at Stanford University (2010). The Project Delivery Process at Stanford Version 2.0, http://lbre.stanford.edu/sites/all/lbre-shared/files/docs_public/PDP_BrochureAugust2010.pdf, (accessed November 21, 2013).

Kats, G., Alevantis, L., Berman, A., Mills, E., and Perlman, J. (2003). The Costs and Financial Benefits of Green Building: A Report to California's Sustainable Building Task Force, http://www.usgbc.org/Docs/News/News477.pdf, (accessed November 3, 2013).

Kok, N., McGraw, M., and Quigley, J. M. (2011). The Diffusion of Energy Efficiency in Building, *American Economic Review*, 101(2).

Lützkendorf, T. and Lorenz, D., 2005, Sustainable Property Investment: Valuing sustainable buildings through property performance assessment, *Building Research & Information*, Vol. 33, No. 3, pp. 212-234.

Mayor's Office of Long-Term Planning and Sustainability (2012). New York City Local Law 84 Benchmarking Report, http://www.nyc.gov/html/gbee/downloads/pdf/nyc_ll84_benchmarking_report_2012.pdf, (accessed November 12, 2013).

Metro Transportation Authority (2013). Facts and Figures - Subways, http://web.mta.info/nyct/facts/ffsubway.htm, (accessed November 25, 2013).

Moss, M. L., Qing, C. Y., and Kaufman, S. (2012). Commuting to Manhattan: A Study of Residence Location Trends for Manhattan Workers from 2002 to 2009. NYU Wagner, http://wagner.nyu.edu/files/faculty/publications/ManhattanCommuting.pdf, (accessed November 21, 2013).

Muldavin, S. R. (2010). Value Beyond Cost Saving: How to Underwrite Sustainable Properties, The Muldavin Company, Inc. ISBN 978-0-9826357-0-4.

New York City Department of Finance (2013). NYC Residential Property Taxes: Class Two – Coops Condos Rentals 4+ units, http://www.nyc.gov/html/dof/downloads/pdf/brochures/class_2_guide.pdf, (accessed October 31, 2013).

Popescu, D., Mladin, E. C., Boazu, R., and Bienert, S. (2009). Methodology for Real Estate Appraisal of Green Value, *Environmental Engineering and Management Journal*, 8(3), 601-606.

Ries, R., Bilec, M. M., Gokhan, N. M., and Needy, K. L. (2006). The Economic Benefits of Green Buildings: A Comprehensive Case Study, *The Engineering Economist*, 51(3), 259-295.

Sanderford, D. (2013). Bridging the Diffusion of Innovation Chasm for Green Housing, Dissertation, Virginia Tech, Blacksburg, VA.

Scofield J. H. (2009). A Re-examination of the NBI LEED Building Energy Consumption Study, 2009 Energy Program Evaluation Conference, Portland, OR.

Stanford Capital Planning Land, Buildings and Real Estate (2002). Stanford Sustainable Guidelines, http://sustainable.stanford.edu/sites/sem.stanford.edu/files/documents/Stanford_sustainable_guidelines.pdf, (accessed Nov 22, 2013).

The Secretariat of the Commission for Environmental Cooperation (2008). Green Building in North America: Opportunities and Challenges, Commission for Environmental Cooperation, Montreal, Canada, ISBN 2-923358-47-3.

U.S. Department of Energy (2008). Energy Efficiency Trends in Residential and Commercial Buildings. http://apps1.eere.energy.gov/buildings/publications/pdfs/corporate/bt_stateindustry.pdf, (accessed November 22, 2013).

U.S. Environmental Protection Agency (2004). Energy Star Labeled Building Profile: First National Bank Center, San Diego, California, www.energystar.gov/index.cfm?fuseaction=labeled_buildings.showProfile&profile_id=1357, (accessed on August 20, 2013).

U.S. Environmental Protection Agency (2006). Summary of The Financial Benefits of Energy Star Labeled Office Buildings, EPA 430-S-06-003.

U.S. Environmental Protection Agency (2013). Energy Star Overview of 2012 Achievements, http://www.energystar.gov/ia/partners/publications/pubdocs/ES%20bi-fold%20031313%20FINAL%20for%20print%20rev.pdf?b5fb-2f46, (accessed August 20, 2013).

Von Neida, B. and Hicks, T. W. (2002). Building Performance Defined: The ENERGY STAR National Energy Performance Rating System, Association of Energy Services Professionals.

Yu, S., Tu, Y., and Luo, C. (2011). Green Retrofitting Costs and Benefits: A New Research Agenda, Institute Real Estate Studies Working Paper Series, the Department of Real Estate, National University of Singapore, Singapore.