# The Effectiveness of Korea Green Building Certification System in terms of Sustainable Development

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## Abstract

Since 1980, there have been widespread efforts by international organizations, governments, and research centers to achieve sustainable development of buildings. In Korea, green building certification has been developed and adopted for various types of buildings. However, although research has been conducted regarding the economic benefits of the Korean green building certification system, there is no research comparing average house-values between green building certified and non-certified buildings. In addition, no research has been conducted about the impact of public transit on average house-values in certified green buildings. The objective of this study, first, is to investigate the economic benefits of green certified buildings by using average house-values index and second, to identify how public transit affects building values. According to the findings, house-values for the green certified buildings are higher than for non-certified buildings. Second, house values increase with proximity to bus stops. These results reflect the potential economic gain from the Korean green building certification system (K-GBCS). In addition, by illustrating the economic benefits of the system, this study could encourage major stakeholders to use the K-GBCS.

**Keywords:** Korea green building certification, house-values, public transits, analysis of variance, regression analysis

## 1. Introduction

Since the end of 1980, the efforts to achieve sustainable development of buildings have been widely conducted by international organizations, governments, research centers, etc. Among the countries promoting sustainable development, the Environmental Assessment Method of Building Research Establishment in UK (BREEAM) and Leadership in Energy and Environmental Design of U.S. Green Building Council (LEED) have been widely adopted. In Korea, green building certification has been developed and adopted for various building types since the Korea Green Building Council (KGBC) was formed in 2002.

However, according to Kibert, it was reported that the green building certification system increases construction time and costs compared with uncertified construction due to the various demands of the certification process [1]. For example, meeting LEED criteria entails the additional time, effort, and cost of documentation, extra research and design, commissioning and modeling for compliance, construction, and preparation of LEED reports. Thus, the public has perceived that green certified buildings are more expensive than traditional buildings. In this respect, some researchers have investigated the economic benefits of the green building certification system.

In Korea, although several studies have been conducted regarding the economic benefits of Korean Green Building Certification System (K-GBCS), there is no research for comparing average house-values between green building certified and non-certified buildings. In addition, no research has been conducted concerning the impact of public transit on average house-values for both green certified and non-certified buildings. Therefore, the objectives of this study are to investigate the economic benefits of green certified building by using average house-values index for three years and to identify the impact of public transit on both green certified and non-certified building. As the population of interest, the Seoul and Gyeonggi provinces were selected since both regions have well-organized transportation systems and sufficient sample sizes.

If the average house-values of green certified buildings are greater than those for non-certified buildings, adopting the green certification system could produce long term economic benefits over non-certified buildings despite initial construction costs. In addition, by analyzing the importance of access to public transportation, this study could be utilized to promote access to public transportation as a criterion for the green certification system.

## 2. Literature review

### 2.1 Green building certification systems

LEED certification is the leading program for designing and building commercial, institutional, government, and high-rise residential buildings of all sizes in a way that produces quantifiable benefits for occupants, the environment and their owners [2]. Specifically, the U.S. green building council established LEED to provide a concise framework for identifying and implementing practical and measurable green building design, construction, operations and maintenance solutions. The LEED criteria consist of seven categories including sustainable sites, water efficiency, energy & atmosphere, materials & resources, indoor environmental quality, innovation in design, and regional priority.

BREEAM has been another widely adopted green certification systems since it was started in 1990 [3]. A BREEAM assessment is used to evaluate a building's specification, design, construction and use regarding a broad range of categories and criteria from energy to

ecology. Assessments include aspects related to energy and water use, the internal environment (health and well-being), pollution, transport, materials, waste, ecology, and management processes.
Currently, these green building certification systems have only focused on the environmental impact. To achieve sustainable development, social, environmental, and economic improvement should be conducted together. Even though some researchers have investigated the impact of the green certification systems, the benefits are limited to the social and environment impacts.
Recently, a few studies have investigated the economic impact of LEED for New Construction (LEED-NC) on land value [4-6]. The results of the studies confirmed that there is significant relationship between LEED-NC Public Transportation Access criteria (PTA) and land value. In this respect, this study focused on the impact of public transit on the house-values of green certified buildings.

### 2.2 Korea green building certification system

To encourage sustainable development in Korea's construction industry, the K-GBCS was started in 2002. K-GBCS is defined as a system which authorizes green building certification for buildings which contribute to saving operating energy as well as reducing environmental pollutants across the life cycle of the building [7]. Therefore, the K-GBCS aims to create sustainable development including social, economic, and environmental development similarly to LEED and BREEAM.
Currently, the K-GBCS is being widely adopted by the Korean construction industry, and approximately 950 buildings have been certified since 2002. However, because the performance evaluation of the K-GBCS has only focused on energy savings, the economic effectiveness has not been sufficiently considered. In addition, as only the energy costs are considered in the K-GBCS, the public has perceived that K-GBCS is not economically beneficial even though there are several incentives from the government.

### 2.3 Previous studies

Many researchers have investigated factors related to house-values. First, researchers have examined the impact of land use such as parks and wetlands and views of water-covered areas on house-values [8-10]. Second, researchers have investigated how proximity to public transit affects house-values [11-13]. Third, some researchers have investigated the economic impact of K-GBCS [14].
However, although several studies have been conducted regarding the economic benefits of K-GBCS, there is no research comparing average house-values between green certified and non-certified buildings. In addition, no research has been conducted about the impact of public transit on average house-values in both types of buildings. Therefore, this study has focused on the economic benefits of green certified buildings and the impact of public transit.

## 3. Data collection methods

Types of K-GBCS buildings are shown in Table 1. The six building uses under K-GBCS are apartments, complexes, offices, schools, accommodations, and stores. Among those, apartments account for 35.1% of total certified buildings. The 20 apartments are awarded as the first grade and 330 apartments are certified as the second grade. This study focused on green certified apartment buildings.

Table 1. Green certified buildings in Korea

| Type | Grade | |
|---|---|---|
| | First | Second |
| Apartment | 20 | 330 |
| Complex | 2 | 15 |
| Accommodation | 0 | 8 |
| Office | 32 | 92 |
| Store | 1 | 9 |
| School | 1 | 486 |
| Total | 56 | 940 |

To compare the average house-values between the Green Certified (GCB) and Non Certified Buildings (NCB) for three years, the sampling process is as follows: first, out of all the green certified apartments, 238 apartments in Seoul and Gyeonggi province were selected. Second, to control for size and age, green certified apartments with an area of 85m$^2$ built in 2010 were selected. As shown in Figure 1(a), 25 green certified apartments were selected. Third, as shown in Figure 2(b), as the treatment group, three non-certified buildings with similar conditions and located within 0.5 km of the green certified building were chosen. Figure 1 (a) represents the green certified buildings included in this study, and Figure 1 (b) shows the process for selecting the three non-certified buildings.

(a) (b)


Figure 1. Green certified (a) and non-certified (b) building sampling.

Since average house-values are affected by macroscopic variables such as the population level of education, population density, and public transportation accessibility, house-values from each region were analyzed separately. Therefore, after sampling, the Average House-values Index (AHI) is utilized in order to analyze the average house-values from 2010 to 2012.

$$AHI_{ij} = \frac{HV_{ij}}{\{\frac{1}{N} \times \sum_{j=1}^{4} HV_{ij}\}}$$

Where,

i = i$^{th}$ region, j = j$^{th}$ building,

N = the number of samples in the i$^{th}$ region,

$AHI_{ij}$ = average house-values index of i$^{th}$ region and j$^{th}$ building

$HV_{ij}$ = house values of the i$^{th}$ region and j$^{th}$ building

The AHI is a relative index according to the average of four samples in each region including GCB and NCB. Therefore, in the i$^{th}$ region, the AHI of the j$^{th}$ building can be estimated using Equation (1). If the AHI of a building is higher than 1, it means that the value of the building is higher than the average of the three nearby buildings. Otherwise, if the AHI is less than 1, it indicates that the value of the building is lower than others.

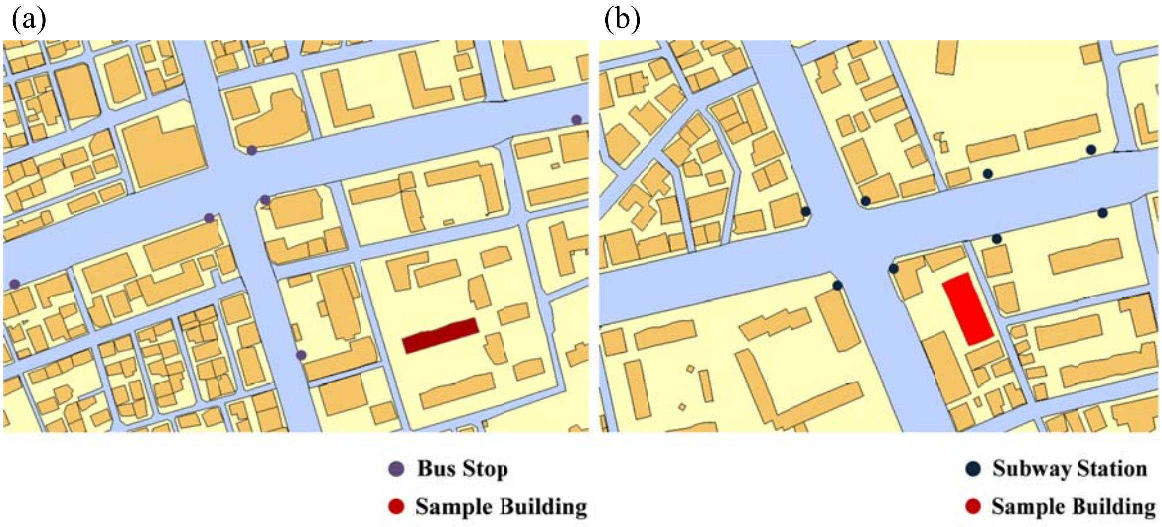


Figure 2. The estimation of the distance from a building to bus stop (a) and subway station (b)

In addition, to determine accessibility of public transportation for GCB and NCB, the closest bus stop was mapped in a GIS map, and distance was recorded (Figure. 2(a)). Distance to the nearest subway station was recorded in the same way (Figure. 2(b)). Table 2 presents data on the house values from 2010 to 2012, AHI, and distance from each building to the closest bus and subway stations.

Table 2. Collected data: construction year, AHI, the distance to closest bus and subway.

| Region | ID | G | CY | AHI | Bus(m) | Subway (m) | Region | ID | G | CY | AHI | Bus(m) | Subway (m) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A | 1 | GCB | 2010.01 | 2.8 | 206 | 913 | M | 51 | NCB | 2010.04 | 0.3 | 141 | 2,000 |
| | 2 | NCB | 2007.02 | 2.14 | 104 | 624 | | 52 | NCB | 2010.06 | 0.24 | 165 | 2,010 |
| | 3 | NCB | 2008.04 | 2.08 | 119 | 246 | N | 53 | GCB | 2010.08 | 2.62 | 93 | 1,290 |
| | 4 | NCB | 2010.07 | 2.45 | 54 | 463 | | 54 | NCB | 2009.09 | 1.42 | 202 | 577 |
| B | 5 | GCB | 2009.03 | 2.39 | 65 | 1,280 | | 55 | NCB | 2010.06 | 0 | 244 | 2,190 |
| | 6 | NCB | 2009.01 | 2.27 | 122 | 500 | | 56 | NCB | 2010.06 | 2.49 | 175 | 1,090 |
| | 7 | NCB | 2010.01 | 1.97 | 213 | 1,090 | P | 57 | GCB | 2010.08 | 1.86 | 145 | 1,475 |
| | 8 | NCB | 2008.06 | 0 | 84 | 1,090 | | 58 | NCB | 2010.04 | 1.19 | 141 | 2,000 |
| C | 9 | GCB | 2010.04 | 1.95 | 91 | 104 | | 59 | NCB | 2010.06 | 1.67 | 165 | 2,010 |
| | 10 | NCB | 2008.02 | 1.62 | 66 | 559 | | 60 | NCB | 2009.09 | 1.61 | 202 | 577 |
| | 11 | NCB | 2010.03 | 0.8 | 176 | 450 | Q | 61 | GCB | 2010.07 | 1.1 | 189 | 1,191 |
| | 12 | NCB | 2009.11 | 1.35 | 206 | 204 | | 62 | NCB | 2010.06 | 1.82 | 244 | 2,190 |
| D | 13 | GCB | 2010.08 | 0.88 | 213 | 324 | | 63 | NCB | 2010.06 | 0.46 | 175 | 1,090 |
| | 14 | NCB | 2009.01 | 0.88 | 173 | 713 | | 64 | NCB | 2010.04 | 1.81 | 141 | 2,000 |
| | 15 | NCB | 2008.04 | 1.17 | 53 | 710 | R | 65 | GCB | 2010.03 | 0 | 149 | 1,951 |
| | 16 | NCB | 2009.07 | 0.48 | 90 | 640 | | 66 | NCB | 2010.06 | 1.34 | 165 | 2,010 |
| E | 17 | GCB | 2010.09 | 0.49 | 186 | 475 | | 67 | NCB | 2009.09 | 3.82 | 202 | 577 |
| | 18 | NCB | 2010.06 | 2.93 | 196 | 652 | | 68 | NCB | 2010.06 | 0.68 | 244 | 2,190 |
| | 19 | NCB | 2010.07 | 0.7 | 67 | 835 | S | 69 | GCB | 2010.08 | 2.66 | 175 | 3,392 |
| | 20 | NCB | 2008.01 | 0.86 | 50 | 561 | | 70 | NCB | 2010.08 | 0 | 237 | 6,440 |
| F | 21 | GCB | 2010.06 | 1 | 46 | 305 | | 71 | NCB | 2010.07 | 0.75 | 118 | 6,660 |
| | 22 | NCB | 2010.09 | 2 | 194 | 502 | | 72 | NCB | 2009.11 | 2.15 | 207 | 6,220 |
| | 23 | NCB | 2010.07 | 2.38 | 67 | 835 | T | 73 | GCB | 2010.07 | 0.26 | 132 | 2,864 |
| | 24 | NCB | 2008.01 | 0.29 | 50 | 561 | | 74 | NCB | 2010.08 | 1.02 | 237 | 6,440 |
| G | 25 | GCB | 2010.07 | 0.78 | 165 | 841 | | 75 | NCB | 2010.07 | 0 | 118 | 6,660 |
| | 26 | NCB | 2010.09 | 2.92 | 194 | 502 | | 76 | NCB | 2009.11 | 0.76 | 207 | 6,220 |
| | 27 | NCB | 2010.06 | 1.71 | 196 | 652 | U | 77 | GCB | 2010.08 | 2.24 | 76 | 3,075 |
| | 28 | NCB | 2008.01 | 1.01 | 50 | 561 | | 78 | NCB | 2010.08 | 0 | 237 | 6,440 |
| H | 29 | GCB | 2010.01 | 0.98 | 137 | 141 | | 79 | NCB | 2010.07 | 2.16 | 118 | 6,660 |
| | 30 | NCB | 2009.07 | 2.09 | 184 | 476 | | 80 | NCB | 2009.11 | 2.56 | 207 | 6,220 |
| | 31 | NCB | 2009.03 | 2.07 | 165 | 173 | V | 81 | GCB | 2010.02 | 0 | 99 | 1,173 |
| | 32 | NCB | 2010.02 | 1.28 | 211 | 494 | | 82 | NCB | 2009.07 | 1.41 | 96 | 1,560 |
| I | 33 | GCB | 2010.11 | 0 | 178 | 661 | | 83 | NCB | 2010.05 | 2.11 | 73 | 931 |
| | 34 | NCB | 2008.02 | 0 | 84 | 964 | | 84 | NCB | 2010.02 | 0 | 61 | 2,195 |
| | 35 | NCB | 2008.12 | 1.57 | 215 | 1,490 | W | 85 | GCB | 2010.02 | 1.44 | 211 | 1,184 |
| | 36 | NCB | 2010.08 | 1.3 | 108 | 290 | | 86 | NCB | 2010.04 | 0 | 117 | 1,425 |
| J | 37 | GCB | 2010.02 | 2.52 | 123 | 221 | | 87 | NCB | 2010.05 | 1.98 | 73 | 931 |
| | 38 | NCB | 2008.12 | 2.07 | 129 | 126 | | 88 | NCB | 2010.02 | 0.8 | 61 | 2,195 |
| | 39 | NCB | 2009.03 | 0.34 | 106 | 225 | X | 89 | GCB | 2010.06 | 0.7 | 151 | 2,435 |
| | 40 | NCB | 2007.06 | 0 | 411 | 343 | | 90 | NCB | 2010.05 | 1.06 | 98 | 945 |
| K | 41 | GCB | 2010.05 | 1.08 | 172 | 812 | | 91 | NCB | 2009.11 | 0 | 188 | 642 |
| | 42 | NCB | 2007.09 | 0.86 | 88 | 615 | | 92 | NCB | 2009.07 | 3.93 | 93 | 688 |
| | 43 | NCB | 2010.05 | 0 | 189 | 379 | Y | 93 | GCB | 2010.03 | 2.75 | 114 | 1,924 |
| | 44 | NCB | 2010.12 | 2.88 | 166 | 1,210 | | 94 | NCB | 2010.02 | 0 | 84 | 6,912 |
| L | 45 | GCB | 2010.05 | 0.96 | 85 | 959 | | 95 | NCB | 2009.07 | 1.21 | 238 | 7,521 |
| | 46 | NCB | 2010.12 | 0 | 166 | 1,210 | | 96 | NCB | 2009.11 | 0.86 | 206 | 10,071 |
| | 47 | NCB | 2010.05 | 0.39 | 189 | 379 | Z | 97 | GCB | 2010.08 | 1.25 | 156 | 10,451 |
| | 48 | NCB | 2007.02 | 1.44 | 151 | 556 | | 98 | NCB | 2010.12 | 0.9 | 104 | 6,923 |
| M | 49 | GCB | 2010.06 | 0.8 | 188 | 1,590 | | 99 | NCB | 2009.05 | 0.8 | 144 | 8,075 |
| | 50 | NCB | 2010.06 | 0.2 | 175 | 1,090 | | 100 | NCB | 2008.04 | 0.8 | 109 | 8,021 |

## 4. Data analysis

### 4.1 ANOVA test for GCB and NCB

Table 3 shows descriptive statistics for both NCB and GCB. According to this descriptive analysis, the AHI mean for the GCB group is relatively higher than that for the NCB group. An analysis of variance (ANOVA) is used to test for differences among the means of two or more groups.

Table 3. Descriptive statistics for the NCB and GCB groups

| | NCB | GCB |
|---|---|---|
| Mean | 0.853 | 1.243 |
| Standard Deviation | 1.284 | 0.886 |
| Min | -2.62 | -1.62 |
| Max | 2.93 | 3.93 |

In this study, an ANOVA test was used to determine if there were significant differences in the means of NCB and GCB. The following hypotheses were examined in this study.

$$H_0: \mu_{GCB} = \mu_{NCB}$$
$$H_1: \mu_{GCB} \neq \mu_{NCB}$$

Where,
$\mu_{GCB}$: AHI mean for green certified building
$\mu_{NCB}$: AHI mean for non-certified building

The variance of the data to determine statistical difference between two group means was analyzed using an F-test to provide a p-value. With this p-value, the above hypotheses are tested for a decision. In the F-test, if the between-group variability is larger than the within-group variability, $H_0$ could be rejected. In other words, the means of the two tested groups are statistically different. The F-test results are as shown in Table 4. The p-value was 0.036. Therefore, the null hypothesis, that the means of the groups are the same, is rejected. Thus, there was a significant difference between the means of these groups.

Table 4. F-test results

| | Sum of Squares | DF | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Between Groups | 6.512 | 1 | 6.512 | 4.529 | 0.036 |
| Within Groups | 140.927 | 98 | 1.438 | | |
| Total | 147.439 | 99 | | | |

Even though the difference between the means of the groups was statistically significant, F-test satisfies the following assumptions: Independence, Normality, and Equal Variance. In terms of independence, since the sample data were obtained from GIS sources, the data are not related to each other. Therefore, any observation does not provide any information associated with any other observations.

The check for normality of the residual is important since the ANOVA theory is based on this assumption. Therefore, if the residuals are not normally distributed, the results cannot be reasonably accepted. Table 5 represents the Kolmogorov-Smirnov and Shapiro-Wilk tests to check the standard residual normality for GCB and NCB.

Table 5. Numerical analysis to check standard residual normality

| | Kolmogorov-Smirnov | | | Shapiro-Wilk | | |
|---|---|---|---|---|---|---|
| Group | Statistics | DF | Sig. | Statistics | DF | Sig. |
| GCB | 0.132 | 25 | 0.124 | 0.980 | 25 | 0.360 |
| NGB | 0.798 | 75 | 0.132 | 0.979 | 75 | 0.139 |

In general, the Kolmogorov-Smirnov is more valid than the Shapiro-Wilk when the samples number more than 50, while the Shapiro-Wilk is better than Kolmogorov-Smirnov for a smaller number of samples. Since the sample size of NCB is 75, both methods are acceptable. However, for GCB, the Shapiro-Wilk should be used. According to Table 5, the p-values were higher than 0.05, which means the null hypotheses (standard residuals are normally distributed) cannot be rejected. Furthermore, the Q-Q plot and histogram of standardized residuals also showed that the residuals are normally distributed, as shown in Figures 3 (a) and (b). Therefore, the values and figures indicate that there was no heteroscedasticity problem and confirmed the robustness of the data. In addition, to analyze the data, the Cook's distance and Leverage values must be identified. According to the standard residual of variables, there were no outliers in either the NCB or the GCB group.

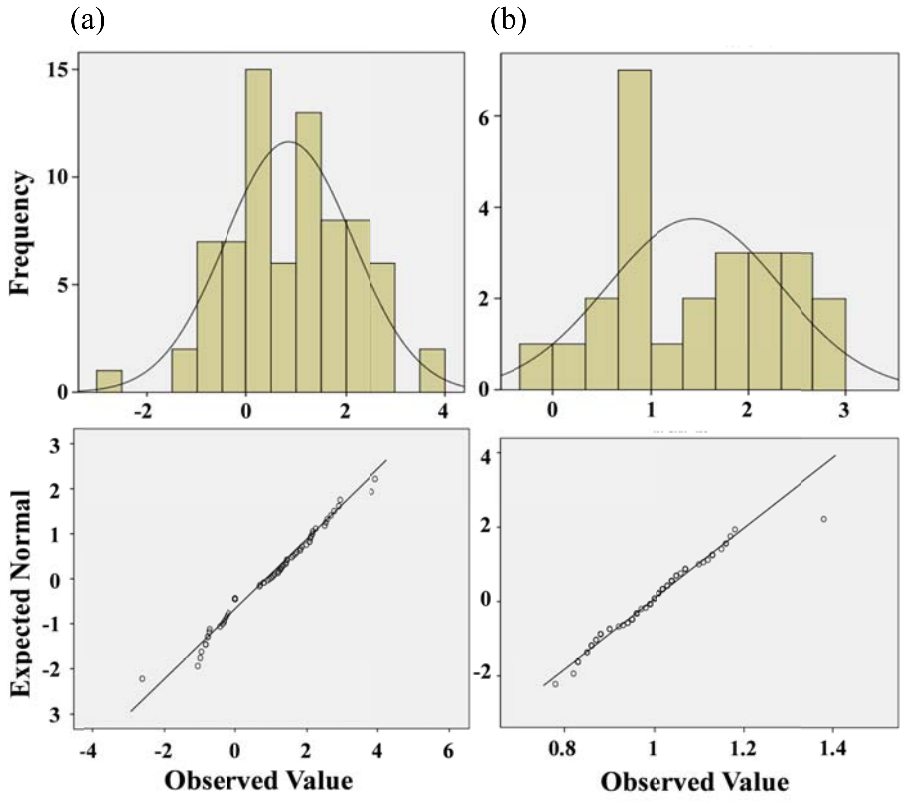


Figure 3. Histograms and Q-Q plot of standard residuals for NCB (a) and GCB (b)

### 4.2 The relationship between public transit and AHI

To investigate the economic impact of public transit such as bus and subway on the AHI of GCB and NCB, the following hypotheses were tested.

(1) There is a significant relationship between the distance to public transit and the average house-values index of both GCB and NCB.
(2) The average house-values index increases as the distance to bus stops decreases.
(3) The average house-values index increases as the distance to subway stations decreases.

In this study, multiple linear regression analysis with one-way ANOVA was performed to determine the impact of public transit such as bus and subway on AHI. The following model is established.

$$AHI = \beta_0 + \beta_1 \cdot G + \beta_2 \cdot BUS + \beta_3 \cdot SUB$$

Where,

AHI: Average house-value index
G: 0, Green certified building, 1, Non-certified building
BUS: Distance from sample to the closest bus stop
SUB: Distance from sample to the closest subway station

Before proceeding to interpretation of the regression model, it is essential to determine if the residuals are normally distributed. Table 6 represents the check for normality of the model. Kolmogorov-Smirnov and Shapiro-Wilk values confirmed that the residuals of the model were normally distributed since the p-value is higher than 0.05.

Table 6. Numerical analysis to check standard residual normality

| | Kolmogorov-Smirnov | | | Sharpiro-Wilk | | |
|---|---|---|---|---|---|---|
| | Statistics | DF | Sig. | Statistics | DF | Sig. |
| Standardized Residual | 0.094 | 99 | 0.057 | 0.983 | 99 | 0.322 |

Furthermore, the Q-Q plot and histogram of standardized residuals also showed that the model is normally distributed, as shown in Figures 4 (a) and (b). Therefore, there was no heteroscedasticity problem, and the robustness of the data was confirmed. In addition, the regression model was significant in testing the hypothesis.

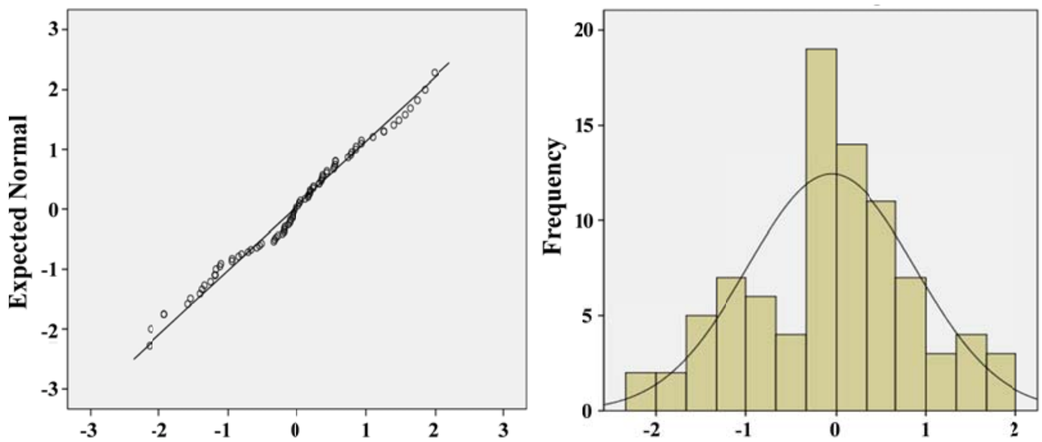


Figure 4. Histograms and Q-Q plot of standard residuals for the regression model

Table 7 shows the coefficients of the model developed in this study. As a categorical variable, G represents the GCB and NCB buildings. When the G is 0, it represents the GCB buildings, and when G is 1, it represents the NCB buildings. As shown in Table 6, there are significant relationships between the intercept, G, the Bus variable and AHI. However, the Subway variable is not related to the AHI. In addition, there was no multi-collinearity problem of the model since the Variance Inflation Factor (VIF) ranged from 1.01 to 1.06. The adjusted R-square of the model was 0.313, which suggests that the 31.3% variability in AHI could be explained by these variables.

Table 7. Coefficient results

| Variable | B | Std. Error | t-value | p-value | VIF |
|---|---|---|---|---|---|
| (Constant) | 0.894 | 0.026 | 34.572 | | |
| G | 0.038 | 0.020 | 4.194 | 0.000 | 1.060 |
| BUS | -0.071 | 0.035 | -4.189 | 0.000 | 1.070 |
| SUB | 0.038 | 0.020 | 1.889 | 0.371 | 1.010 |

*Dependent variable: AHI

Equations (3) and (4) based on the coefficients analyzed in this study were developed to investigate how AHI is affected by public transit such as bus and subway. Equation (3) represents the model for GCB, and Equation (4) indicates the model for NCB. As shown in Equations (3) and (4), for both GCB and NCB, there is negative relationship between the AHI and the distance from the sample to the bus stop. This indicates that the AHI increases with proximity to a bus stop, but there is not a significant relationship between AHI and subway stations ($p>0.05$, Table 6). In addition, according to Equations (3) and (4), the AHIGCB value is higher than AHINCB due to the intercept. This result verified the ANOVA test conducted in this study.

$$AHI_{GCB} = 0.932 - 0.071 \cdot BUS + 0.038 \cdot SUB \quad (3)$$

$$AHI_{NCB} = 0.894 - 0.071 \cdot BUS + 0.038 \cdot SUB \quad (4)$$

## 5. Conclusions

In this study, by investigating the average house-value difference from 2010 to 2012 between green certified buildings and non-certified buildings, it was confirmed that the house-values for green certified buildings were significantly higher than for non-certified buildings. In addition, there was a significant relationship between the average house-values of GCB and NCB and the distance to a bus stop, although distance to a subway stop did not significantly affect house values. Specifically, since the R-square value was 0.313, the model can be reasonably accepted to investigate the relationships between variables. Through the model, it could be concluded that the average house values index increases as the distance to bus stops decreases.

This study investigated the economic benefits of green certified buildings by using average house values. These results may reflect potential economic effectiveness in the actual economic effect of the K-GBCS. Also, since the regression model confirmed that public transit accessibility is a significant factor affecting house-values of GCB, it would be economically beneficial for K-GBCS to integrate the public accessibility criteria into its system. In addition, by demonstrating the economic benefits of GCB, this study could encourage major stakeholders to use K-GBCS.

## Acknowledgements

This work was supported by the National Research Foundation of Korea (NRF) grant funded by the Korea government (MEST) (No. 2012-0000609).

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## Profile

Kiyoung Son studied construction engineering &management. In May, 2012, he received Ph.D degreeat Construction Science Department, Texas A&M University. From 2009 to 2011, he was a Graduate Research Associate of Construction Science department at Texas A&M University.

His current research interests include investigating the impact on the economic benefit of Leadership Environmental and Energy in Design (LEED) rating system. As part of his current research, Mr. Son developed a quantifying model that predicts the unit value of unimproved lands by analyzing the interdependency between LEED components and the appraised unit value of unimproved lands. This study accounted for correlations between them by means of amultipleregression analysis through a GIS mapping process. Inthis research,it was identified thatthere is a significant relationship between appraised land value and the LEED rating system then it could be helpful decision-makers make better-informed decisions whenthey are planning sustainable real-estate development projects that use the LEED rating system

In addition, he has concentrated on the research such as health performance evaluation of buildings, development of construction materials and methods, construction project management, statistical model establishment for construction management, construction information technology. Especially, he has published 13 papers including ASCE/Korean journals and conference proceedings from 2009 to 2011

# The Effectiveness of Korea Green Building Certification System in terms of Sustainable Development

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Texas A&M University

**Sept. 19, 2012**

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## Contents



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INTRODUCTION / BACKGROUND

## Importance of Research

1. Growth of Environmental certification systems

green building council australia

Green Star (Australia)

LEED (USA)

K-GBCS (Korea)

Green Globes

Green Globes (USA)

2. Korea Green Building Certification System (K-GBCS) is the most widely adopted certification in Korea
(for homes, retail, schools, commercial interiors, healthcare etc.)

- Currently, there are approximately 1,000 K-GBCS certified projects since 2000

3. Among them, apartment project occupies 35.1% of total certified buildings

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INTRODUCTION / BACKGROUND

## Effectiveness of using Green rating system is debatable

- It has been believed that LEED-NC certified construction projects take longer (Kibert 2005)

- LEED projects involve higher construction cost than typical projects:
an increase of about $2 – $5 per square foot (Rahman and Sadeghpour 2010).

- Green certified buildings are more expensive than traditional buildings

If this study proves adoption of K-GBCS dose have economic benefit, the major stakeholders will encourage to use the K-GBCS to their project.

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## Research objective

**Investigate** the economic impact of Green certified buildings

1. Investigate **the average house-value difference from 2010 to 2012** between Green certified building and non-certified building

2. Identify **the impact of public transit on the average house-value** of Green certified and non-certified buildings on

> If the average house-values of green certified buildings are greater than those for non-certified buildings, adopting the green certification system could produce **long term economic benefits** over non-certified buildings despite initial construction costs.

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## Data collection methods

1. Population:
   Seoul and Gyeonggi provinces
2. Identify all Green certified buildings
3. Select apartment project with non-certified building within 0.5km
4. Perform multiple regression analysis to investigate the average house value differences

Data collection

Data Analysis

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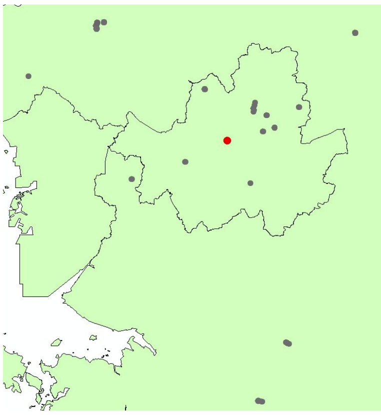
## Data collection methods



● Seoul City Hall
● Green Certified Building

1. Out of all the green certified apartments, 238 apartments in Seoul and Gyeonggi province were selected.

2. To control for size and age, green certified apartments with an area of 85m$^2$ built in 2010 were selected.

3. 25 green certified apartments were selected.

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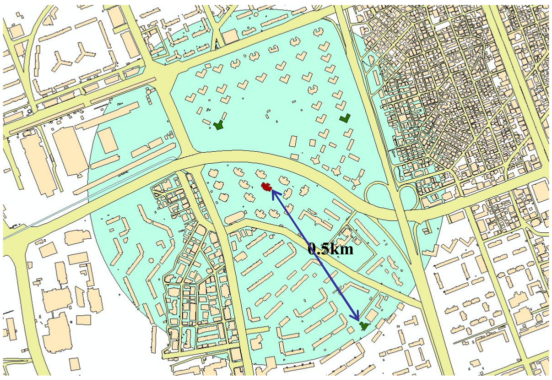
## Data collection methods




● Green Certified Building
● Non-Certified Building

4. As the treatment group, three non-certified buildings with similar conditions and located within 0.5 km of the green certified building were chosen.

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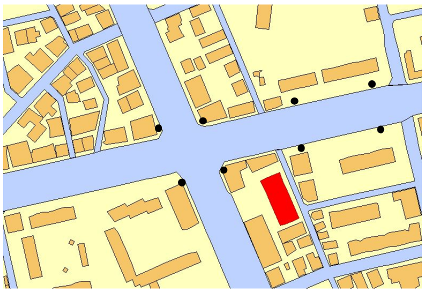
## Data collection methods





5. to investigate the impact of public transits for GCB and NCB, the closest bus stop was mapped in a GIS map, and distance was recorded. In addition, distance to the nearest subway station was recorded in the same way.

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## Data collection methods

**The Average House-values Index (AHI):**

$$AHI_{ij} = \frac{HV_{ij}}{\{\frac{1}{N} \times \sum_{j=1}^{4} HV_{ij}\}} \qquad \text{Equation (1)}$$

Where,
i = i[th] region, j = j[th] building,
N = the number of samples in the i[th] region,
$AHI_{ij}$ = average house-values index of i[th] region and j[th] building
$HV_{ij}$ = house values of the i[th] region and j[th] building

The AHI is a relative index according to the average of four samples in each region including GCB and NCB. Therefore, in the i[th] region, the AHI of the j[th] building can be estimated using Equation (1).

If the AHI of a building is higher than 1, it means that the value of the building is higher than the average of the three nearby buildings. Otherwise, if the AHI is less than 1, it indicates that the value of the building is lower than others.

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## Data collection methods

| Region | ID | G | CY | AHI | Bus(m) | Subway (m) | Region | ID | G | CY | AHI | Bus(m) | Subway (m) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A | 1 | GCB | 2010.01 | 2.8 | 206 | 913 | M | 51 | NCB | 2010.04 | 0.3 | 141 | 2,000 |
| | 2 | NCB | 2007.02 | 2.14 | 104 | 624 | | 52 | NCB | 2010.06 | 0.24 | 165 | 2,010 |
| | 3 | NCB | 2008.04 | 2.08 | 119 | 246 | N | 53 | GCB | 2010.08 | 2.62 | 93 | 1,290 |
| | 4 | NCB | 2010.07 | 2.45 | 54 | 463 | | 54 | NCB | 2009.09 | 1.42 | 202 | 577 |
| B | 5 | GCB | 2009.03 | 2.39 | 65 | 1,280 | | 55 | NCB | 2010.06 | 0 | 244 | 2,190 |
| | 6 | NCB | 2009.01 | 2.27 | 122 | 500 | | 56 | NCB | 2010.06 | 2.49 | 175 | 1,090 |
| | 7 | NCB | 2010.01 | 1.97 | 213 | 1,090 | P | 57 | GCB | 2010.08 | 1.86 | 145 | 1,475 |
| | 8 | NCB | 2008.06 | 0 | 84 | 1,090 | | 58 | NCB | 2010.04 | 1.19 | 141 | 2,000 |
| C | 9 | GCB | 2010.04 | 1.95 | 91 | 104 | | 59 | NCB | 2010.06 | 1.67 | 165 | 2,010 |
| | 10 | NCB | 2008.02 | 1.62 | 66 | 559 | | 60 | NCB | 2009.09 | 1.61 | 202 | 577 |
| | 11 | NCB | 2010.03 | 0.8 | 176 | 450 | Q | 61 | GCB | 2010.07 | 1.1 | 189 | 1,191 |
| | 12 | NCB | 2009.11 | 1.35 | 206 | 204 | | 62 | NCB | 2010.06 | 1.82 | 244 | 2,190 |
| D | 13 | GCB | 2010.08 | 0.88 | 213 | 324 | | 63 | NCB | 2010.06 | 0.46 | 175 | 1,090 |
| | 14 | NCB | 2009.01 | 0.88 | 173 | 713 | | 64 | NCB | 2010.04 | 1.81 | 141 | 2,000 |
| | 15 | NCB | 2008.04 | 1.17 | 53 | 710 | R | 65 | GCB | 2010.03 | 0 | 149 | 1,951 |
| | 16 | NCB | 2009.07 | 0.48 | 90 | 640 | | 66 | NCB | 2010.06 | 1.34 | 165 | 2,010 |
| E | 17 | GCB | 2010.09 | 0.49 | 186 | 475 | | 67 | NCB | 2009.09 | 3.82 | 202 | 577 |
| | 18 | NCB | 2010.06 | 2.93 | 196 | 652 | | 68 | NCB | 2010.06 | 0.68 | 244 | 2,190 |
| | 19 | NCB | 2010.07 | 0.7 | 67 | 835 | S | 69 | GCB | 2010.08 | 2.66 | 175 | 3,392 |
| | 20 | NCB | 2008.01 | 0.86 | 50 | 561 | | 70 | NCB | 2010.08 | 0 | 237 | 6,440 |
| F | 21 | GCB | 2010.06 | 1 | 46 | 305 | | 71 | NCB | 2010.07 | 0.75 | 118 | 6,660 |
| | 22 | NCB | 2010.09 | 2 | 194 | 502 | | 72 | NCB | 2009.11 | 2.15 | 207 | 6,220 |
| | 23 | NCB | 2010.07 | 2.38 | 67 | 835 | T | 73 | GCB | 2010.07 | 0.26 | 132 | 2,864 |
| | 24 | NCB | 2008.01 | 0.29 | 50 | 561 | | 74 | NCB | 2010.08 | 1.02 | 237 | 6,440 |
| G | 25 | GCB | 2010.07 | 0.78 | 165 | 841 | | 75 | NCB | 2010.07 | 0 | 118 | 6,660 |
| | 26 | NCB | 2010.09 | 2.92 | 194 | 502 | | 76 | NCB | 2009.11 | 0.76 | 207 | 6,220 |
| | 27 | NCB | 2010.06 | 1.71 | 196 | 652 | U | 77 | GCB | 2010.08 | 2.24 | 76 | 3,075 |
| | 28 | NCB | 2008.01 | 1.01 | 50 | 561 | | 78 | NCB | 2010.08 | 0 | 237 | 6,440 |
| H | 29 | GCB | 2010.01 | 0.98 | 137 | 141 | | 79 | NCB | 2010.07 | 2.16 | 118 | 6,660 |
| | 30 | NCB | 2009.07 | 2.09 | 184 | 476 | | 80 | NCB | 2009.11 | 2.56 | 207 | 6,220 |
| | 31 | NCB | 2009.03 | 2.07 | 165 | 173 | V | 81 | GCB | 2010.02 | 0 | 99 | 1,173 |
| | 32 | NCB | 2010.02 | 1.28 | 211 | 494 | | 82 | NCB | 2009.07 | 1.41 | 96 | 1,560 |
| I | 33 | GCB | 2010.11 | 0 | 178 | 661 | | 83 | NCB | 2010.05 | 2.11 | 73 | 931 |
| | 34 | NCB | 2008.02 | 0 | 84 | 964 | | 84 | NCB | 2010.02 | 0 | 61 | 2,195 |
| | 35 | NCB | 2008.12 | 1.57 | 215 | 1,490 | W | 85 | GCB | 2010.02 | 1.44 | 211 | 1,184 |
| | 36 | NCB | 2010.08 | 1.3 | 108 | 290 | | 86 | NCB | 2010.04 | 0 | 117 | 1,425 |
| J | 37 | GCB | 2010.02 | 2.52 | 123 | 221 | | 87 | NCB | 2010.05 | 1.98 | 73 | 931 |
| | 38 | NCB | 2008.12 | 2.07 | 129 | 126 | | 88 | NCB | 2010.02 | 0.8 | 61 | 2,195 |
| | 39 | NCB | 2009.03 | 0.34 | 106 | 225 | X | 89 | GCB | 2010.06 | 0.7 | 151 | 2,435 |
| | 40 | NCB | 2007.06 | 0 | 411 | 343 | | 90 | NCB | 2010.05 | 1.06 | 98 | 945 |
| K | 41 | GCB | 2010.05 | 1.08 | 172 | 812 | | 91 | NCB | 2009.11 | 0 | 188 | 642 |
| | 42 | NCB | 2007.09 | 0.86 | 88 | 615 | | 92 | NCB | 2009.07 | 3.93 | 93 | 688 |
| | 43 | NCB | 2010.05 | 0 | 189 | 379 | Y | 93 | GCB | 2010.03 | 2.75 | 114 | 1,924 |
| | 44 | NCB | 2010.12 | 2.88 | 166 | 1,210 | | 94 | NCB | 2010.02 | 0 | 84 | 6,912 |
| L | 45 | GCB | 2010.05 | 0.96 | 85 | 959 | | 95 | NCB | 2009.07 | 1.21 | 238 | 7,521 |
| | 46 | NCB | 2010.12 | 0 | 166 | 1,210 | | 96 | NCB | 2009.11 | 0.86 | 206 | 10,071 |
| | 47 | NCB | 2010.05 | 0.39 | 189 | 379 | Z | 97 | GCB | 2010.08 | 1.25 | 156 | 10,451 |
| | 48 | NCB | 2007.02 | 1.44 | 151 | 556 | | 98 | NCB | 2010.12 | 0.9 | 104 | 6,923 |
| M | 49 | GCB | 2010.06 | 0.8 | 188 | 1,590 | | 99 | NCB | 2009.05 | 0.8 | 144 | 8,075 |
| | 50 | NCB | 2010.06 | 0.2 | 175 | 1,090 | | 100 | NCB | 2008.04 | 0.8 | 109 | 8,021 |

**Collected data (25 Green certified buildings):**
**1) construction year, 2) AHI,**
**3) the distance to closest bus and subway.**

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## Data Analysis

### ANOVA test for GCB and NCB

Descriptive statistics of average house values **(AHI)** for the NCB and GCB groups

| | NCB | GCB |
|---|---|---|
| Mean | **0.853** | **1.243** |
| Standard deviation | 1.284 | 0.886 |
| Min | 0.620 | 0.520 |
| Max | 2.930 | 3.920 |

### ANOVA test:

$$H_0 : \mu_{GCB} = \mu_{NCB}$$
$$H_1 : \mu_{GCB} \neq \mu_{NCB}$$

Where,
$\mu_{GCB}$: AHI mean for green certified building
$\mu_{NCB}$: AHI mean for non-certified building

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## Data Analysis

**F-test results**

| | Sum of Square | DF | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Between Groups | 6.512 | 1 | 6.512 | 4.529 | **0.036** |
| Within Groups | 140.927 | 98 | 1.438 | | |
| Total | 147.439 | 99 | | | |

The null hypothesis, that the means of the groups are the same, is rejected.

Thus, there was **a significant difference** between the means of these groups.

The AHI of GCB is significantly higher than the AHI of NCB

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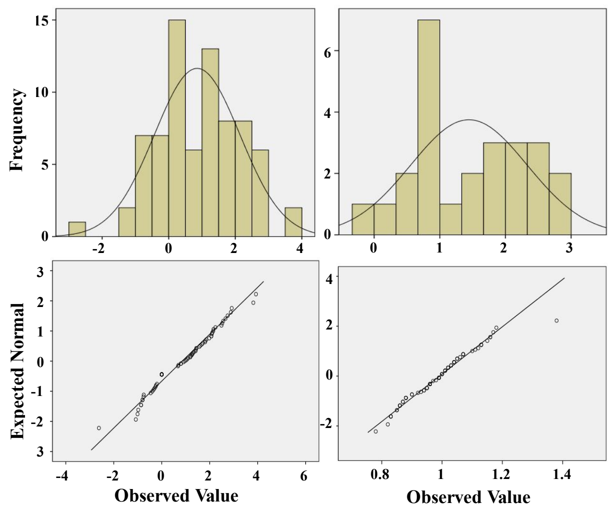
## Data Analysis




**Histograms and Q-Q plot of standard residuals for NCB and GCB**

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## Data Analysis

**The relationship between public transit and AHI**

$AHI = \beta_0 + \beta_1 \cdot G + \beta_2 \cdot BUS + \beta_3 \cdot SUB$

Where,

AHI: Average house-value index
G: 0, Green certified building, 1, Non-certified building
BUS: Distance from sample to the closest bus stop
SUB: Distance from sample to the closest subway station

**Hypothesis**

1. There is a significant relationship between the distance to public transit and the average house-values index of both GCB and NCB.
2. The average house-values index increases as the distance to bus stops decreases.
3. The average house-values index increases as the distance to subway stations decreases.



## Data Analysis

**Coefficient results**

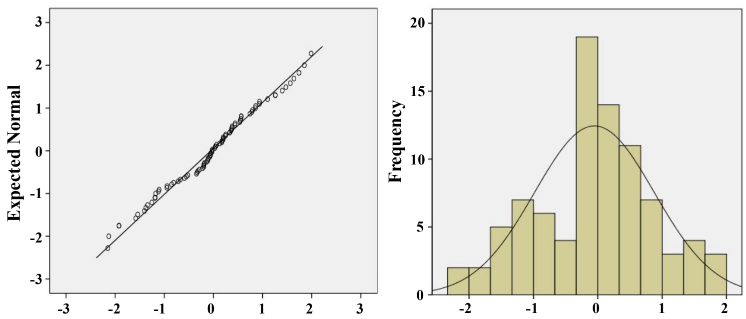
| | B | Std. Error | t-value | P-value | VIF |
|---|---|---|---|---|---|
| (Constant) | 0.894 | 0.026 | 34.572 | | |
| G | 0.038 | 0.020 | 4.194 | 0.000 | 1.060 |
| BUS | -0.071 | 0.035 | -4.189 | 0.000 | 1.070 |
| SUB | 0.038 | 0.020 | 1.889 | 0.371 | 1.010 |

*Dependent variable: AHI

$AHI_{GCB} = 0.932 - 0.071 \cdot BUS + 0.038 \cdot SUB$

$AHI_{NCB} = 0.894 - 0.071 \cdot BUS + 0.038 \cdot SUB$

## Data Analysis




**Histograms and Q-Q plot of standard residuals for the regression model**

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## Conclusions

In this study, by investigating the average house-value difference from 2010 to 2012 between green certified buildings and non-certified buildings, **it was confirmed that the house-values for green certified buildings were significantly higher than for non-certified buildings.**

There was **a significant relationship between the average house-values of GCB and NCB and the distance to a bus stop,** although distance to a subway stop did not significantly affect house values.

Specifically, since **the R-square value was 0.313**, the model can be reasonably accepted to investigate the relationships between variables. Through the model, **it could be concluded that the average house values index increases as the distance to bus stops decreases.**

These results may reflect potential economic effectiveness in the actual economic effect of the K-GBCS.

Also, since the regression model confirmed that public transit accessibility is a significant factor affecting house-values of GCB, it would be economically beneficial for K-GBCS to integrate the public accessibility criteria into its system.

In addition, by demonstrating the economic benefits of GCB, this study could encourage major stakeholders to use K-GBCS.

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