PREDICTING THE UNIT APPRAISAL VALUE

OF THE UNIMPROVED AND PRIVATE LAND IN THE CITY OF HOUSTON

BY LEED SUSTAINABLE SITE CREDITS

A Dissertation

by

YOUNG JUN PARK

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

DOCTOR OF PHILOSOPHY

December 2009

Major Subject: Architecture

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Approved by:

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ABSTRACT

Predicting the Unit Appraisal Value of the Unimproved and Private Land in the City of

Houston by LEED Sustainable Site Credits. (December 2009)

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Co-Chairs of Advisory Committee: Dr. Paul K. Woods
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        The primary objectives of this research are to identify the relation between

Leadership in Energy and Environmental Design (LEED) criteria regarding sustainable

site credits and the appraised value of land parcels in the City of Houston, and

additionally to analyze the effects of detail components which leverage the sustainable

credits regarding the Public Transportation Access (PTA) in terms of economic issues.

To accomplish these objectives, the approach to estimate sustainable ratings of specific

parcels using Geographic Information Systems (GIS) was established.

        Green construction must be one of the most powerful trends in the construction

industry. One of the main concepts to underlie the basis of this green construction is

sustainability. This sustainability has to be considered in the process of the site selection

prior to the actual activities to construct a building. Recently, the U.S. Green Building

Council (USGBC) has suggested the modified guideline with "LEED 2009 for New

Construction and Major Renovations". According to this metric, it is clear that this

principle endeavors to block environmental abuses related to land development or

restoration projects. On the other hand, it is not easy to check the serviceability of these

rules to guarantee continuous economic merit through sustainable land development or restoration encouraged by these criteria.

The criteria regarding the sustainable site selection in this LEED metric are Sustainable Site Credit (SSC) #1: Site Selection, SSC #3: Brownfield, and SSC #4.1: Public Transportation Access. Linear regression methods were used for predictive analysis. In this model, the unit appraisal value of the land was used as the dependent variable to reflect the economic values of the land, and LEED-sustainable-site criteria were used as the categorical independent variables.

According to statistical results, the models to predict the appraisal parcel value using sustainable site components have relatively low R-square. Moreover, SSC #1 and SSC #3 were not significant factors affecting the unit value of land. This outcome means that there are no statistically significant effects of SSC #1 and SSC #3 on parcel value.

On the other hand, SSC #4.1 was highly significant. Furthermore, the detail components of SSC #4.1 regarding the bus stops and railroad stations were also significant. These results can lead to improved environmental preservation by avoiding development which is far from the PTA as well as increasing economic value while enhancing the development density near the PTA corridors.

Finally, GIS was used to determine the LEED ratings of individual parcels. The methods established to do this can be applied to other projects for the other regions, or the same region at different times.

DEDICATION

To Dr. Paul K. Woods, my sincere revered teacher, as well as my unforgettable father.

ACKNOWLEDGEMENTS

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CHAPTER I

INTRODUCTION: THE IMPORTANCE OF THIS RESEARCH

1.1. Research Problem

The comprehensive objectives of this research are to 1) describe the population of the available supply of undeveloped sites which meet sustainable LEED criteria relative to the population of all undeveloped sites in the target area, 2) predict the appraised value ($/ft^2) of unimproved sites in the target area based on their LEED sustainable site selection score, 3) determine the significance and magnitude of the effects of the detail components which define the PTA sustainable site selection score, and 4) develop a formalized process using GIS that can be applied to other cities and at other times to evaluate both the sustainability of individual municipalities and/or provide feedback regarding the viability of LEED guidelines.

1.2. Literature Reviews

USGBC recently published "LEED 2009 for New Construction and Major Renovations". This metric enables one to evaluate SSCs for undeveloped (unimproved) land. The purpose of this metric is to encourage decisions regarding land development

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This dissertation follows the style of *The American Institute of Constructors*.

or restoration projects that limit the environmental impact on the regional ecosystem (USGBC, 2009).

If the resultant sustainable rating assessed with this metric proves to be uncorrelated to economic value, the metric may prove insignificant and need to be revised. This is because sustainable projects for land development/restoration have dual goals: increased economic value and environmental preservation (USGBC, 2009). These aims can be clearly inferred in the underlying basis for each SSC.

1.2.1. LEED Criteria for Sustainable Site

There are three criteria to assess the extent of sustainability for unimproved (no buildings, paving, etc.) sites.

1.2.1.1. SSC #1

The SSC #1(Site Selection) have to lessen environmental abuses and prevent the development of inappropriate lands.

Development is institutionally blocked from constructing facilities on the following sites: prime farmlands, floodable lands, endangered habitats, wetlands, adjacent lands with water bodies, and parklands. A sustainable credit is awarded to the plot which is not characterized by these features (USGBC, 2009).

1.2.1.2.   SSC #3

Brownfield is any site in which development is complicated by present or potential environmental contamination. The project to rehabilitate this site contributes to sustainability by moderating the load on undeveloped lands and saving cost (USGBC, 2009).

Brownfield is designated as a contaminated site by a local, state, or federal government (USGBC, 2009).

Brownfield site means real property, the expansion, redevelopment, or reuse of which may be complicated by the presence or potential presence of a hazardous substance, pollutant, or contaminant (U.S. Environmental Protection Agency, 2008). These can be abandoned buildings, vacant lots, former commercial or manufacturing sites, or other types of property (City of Houston, 2008).

1.2.1.3.   SSC #4.1

Public transportation contributes to reducing pollution, mitigating land development impacts from automobile use, and increasing property value due to higher development density (USGBC, 2009; Sinha, 2003).

A sustainable credit is given to the site which is located within 1/2 mile of commuter rail, light rail, or subway station, or within 1/4 mile of at least one stop for at least two bus lines useable by project occupants (USGBC, 2009).

1.2.2.   Background

1.2.2.1.   Backing

Land development for immediate profit cannot guarantee continuous economic worth. It can, however, ravage the ecological environment in a region (USGBC, 2009).

In Tennessee, annual Vehicle Miles Traveled (VMT) increased by 11.7% from 60.5 to 67.6 billion miles between 1997 and 2001 (U.S. Department of Tranportation, 2001). Due to this increased vehicle use, substantial green fields were encroached by infrastructure such as parking and road surfaces, service stations, fuel distribution networks, etc. Air pollution was aggravated owing to auto exhausts such as smog and particulates. Nevertheless, the Gross Domestic Product (GDP), which received a contribution by increased transit and ground passenger transportation, decreased by 3% from 195 to 189 billion of chained (Year 2000) dollars between 1997 and 2001 (U.S. Department of Commerce, 2001).

1.2.2.2. Grounds

The appraised value of the land can be used as a measure to reflect its economic value because it contains the investment merit as well as the property worth. The components which may affect this price are 1) its location, size, shape, and slope; 2) town planning controls; 3) constraints on use such as heritage restrictions; 4) any rights connected with ownership of the land such as water rights; and 5) nearby development and amenities such as parks, views, public transport, and busy roads. In other words, the appraised price of the land is influenced by merits and demerits that are created by these

factors (Benhamin, Guttery, & Sirmans, 2004; Boddy, 2002; Lins, 2005).

Furthermore, according to the LEED metric, restrictions on land use such as the preservation of prime farmland, habitat, and surface water, brownfield rehabilitation, and public transportation are also important components which affect the sustainable rating for the preservation of the environment and higher associated land values. Therefore, it is very likely that this sustainable rating of the site should be related to the appraised value of the land.

1.2.2.3. Warrant

In addtion, one of the most popular projects regarding sustainable development is the redevelopment of brownfields. Many cities are trying to rehabilitate brownfield sites within their city limits while pursuing economic and environmental benefits through land development projects. For example, the City of Houston launched a project to restore polluted brownfield sites by means of planned activities such as advocating cleanup. This project also played a hand in facilitating redevelopment of the local brownfield properties in order to supply jobs, upgrade the quality of life, and assist the rehabilitation of nearby real estate (City of Houston, 2008).

Lastly, in the City of New York, although the annual VMT increased by 8.2% from 120.8 to 130.7 billion miles between 1997 and 2001 (U.S. Department of Tranportation, 2001), the GDP contributed by the transit and ground passenger transportation increased more than 13.5% from 2,379 to 2,699 billions of chained (2000) dollars over the same period unlike Tennessee (U.S. Department of Commerce, 2001).

The main reason for this economic result was due to the availability of convenient public transit and effective urban planning (People-Powered Sustainability Guide, 2008). In this regard, there may be good ways to pursue land development while, at the same time, preserving the environment. Actually, the City of New York was ranked as the most sustainable city among the 50 biggest cities in the US, while the City of Memphis in Tennessee was assessed as the worst city in terms of sustainability (People-Powered Sustainability Guide, 2008). In fact, 54.63% of the residents in New York City (NYC) use public transit for city commuting and 9.44% walk to work. Furthermore, NYC has about 20% of its land devoted to parks (People-Powered Sustainability Guide, 2008). As a matter of fact, public transit contributes to development density and community connectivity due to more users and residents. Furthermore, public transit contributes to an agreeable urban environment with less use of private vehicles (Sinha, 2003). Consequently, these positive aspects of transit can raise the sustainable rating of sites and their value.

Thus, the components that contribute to a LEED sustainable rating such as public transit, brownfield, and restriction for environmental preservation can affect the economic value of the land as well as ecology. Thus, considering variables that contribute to both the LEED sustainable rating and the value of land, there may be a specific relationship between them and this relationship can affect decisions regarding land development.

1.2.2.4. Claims

Sustainable development activities hopefully guarantee long-term increases in economic value. Environmental abuses caused by imprudent development may result in immediate economic worth but may result in long-term economic and environmental disaster. Lands which have higher LEED ratings may be more appropriate to develop thus creating increased economic merits as well as preserving green environments than the lands which have lower LEED ratings.

LEED metrics can be used in the selection and development of sustainable sites as a guideline. However, if the sustainable rating of the site has nothing to do with land value, the metric to assess sustainable rating may be impractical for both development and environmental preservation. Thus, it is important to identify how much the sustainable rating is related to value.

There could be the various ways to estimate and predict the appraised value of land. However, the model to predict appraised value should also be meaningful for not only predicting the appraised value but also identifying the significance of each of the sustainable criteria and components which constitute the sustainable criteria.

Public transportation can discourage inappropriate development or restoration activities for land which needs to be protected ecologically by inducing the land development or restoration activities for land near PTA. This development can also affect the economic worth of land near PTA and could gradually increase their population densities.

There are various ways to estimate LEED sustainable ratings such as a field

observation. However, geographic analysis could be one of the most effective and convenient methods to do this. Furthermore, if a standard approach to analyze a LEED rating using GIS is devised, this can be applied to individual parcels for other projects regarding LEED sustainable sites.

1.3. Importance and Expected Benefits

1.3.1. Description of LEED Sites

If the suggested models are valid in identifying the relation between the LEED SSC and the value of the unimproved land, it can provide significant support for the serviceability of the metrics as an effective guideline to pursue development and conservation together.

1.3.2. Prediction of Appraised Value

Through established statistical models, we can assess the actual contribution or effect of each component considered in granting a sustainable rating such as land states, PTA, and brownfields. Otherwise, if the suggested models are not validated, this could identify market opportunities where full parcel value is not yet broadly recognized.

1.3.3. Public Transportation Access

It is possible to identify the effect of PTA on appraised land values. Furthermore, this information regarding sustainable ratings impacted by PTA could be used to encourage investment in public transportation infrastructure for land development.

1.3.4. GIS Process

LEED rating maps which are constructed by GIS could be the powerful resources to determine the sustainability of the specific sites graphically. Furthermore, the process developed to evaluate LEED sustainable ratings with GIS can be applied to the other projects for the other regions or for the same area but at a different time.

CHAPTER II

PROBLEM STATEMENT

2.1.   Sub-Problems

2.1.1.   Descriptive Statistics

2.1.1.1.   Population

- It is possible to find the population and count the number of parcels in the population through GIS.

- The percentage of the population will not exceed 10% of the entire number of parcels in the City of Houston and 5% of the whole parcels in Harris County.

- The mean of the population will be higher than the means of the whole parcels in the City of Houston and in Harris County.

2.1.1.2.   Overall Model

- It is possible to find parcels which are inappropriate for land development or restoration projects and count these parcels through GIS.

- The percentage of these parcels will not exceed 10% of the whole parcels in the City of Houston and 5% of the whole parcels in Harris County.

- The mean of these will be significantly lower than the means of the whole parcels within the City of Houston and in Harris County.

- It is possible to find parcels for the brownfield and count these parcels through GIS.

- The percentage of these parcels will not exceed 10% of the whole parcels in the City

of Houston and 5% of the whole parcels in Harris County.

- The mean of these will be significantly higher than the means of the whole parcels in the City of Houston and in Harris County.

- It is possible to find parcels which satisfy the conditions for PTA and count these parcels through GIS.

- The percentage of these parcels will not exceed 10% of the whole parcels in the City of Houston and 5% of the whole parcels in Harris County.

- The mean of these will be significantly higher than the means of the whole parcels in the City of Houston and in Harris County.

2.1.1.3.   Public Transportation Access Model

- It is possible to find parcels which satisfy the condition for bus stops of PTA and count these parcels through GIS.

- The percentage of these parcels will not exceed 10% of the whole parcels in the City of Houston and 5% of the whole parcels in Harris County.

- The mean of these will be significantly higher than the means of the whole parcels within the City of Houston and in Harris County.

- It is possible to find parcels which satisfy the condition for light rail stations of PTA and count these parcels through GIS.

- The percentage of these parcels will not exceed 10% of the whole parcels in the City of Houston and 5% of the whole parcels in Harris County.

- The mean of these will be significantly higher than the means of the whole parcels

in the City of Houston and in Harris County.

2.1.2. Overall Model

- Predict model to calculate parcel unit value ($/sf^2) based on the SSC #1, #3, and #4.1

- Identify which SSC #1, #3, and #4.1, are statistically significant contributors to parcel unit value.

- Identify the difference in magnitude of the unit values between treatment and control parcels for each statistically significant SSC.

2.1.3. Public Transportation Access Model

- Establish a predictive model to calculate parcel unit value ($/ft^2) based on components of the SSC #4.1.

- Identify which components of the SSC #4.1, are statistically significant contributors to parcel unit value.

- Identify the difference in magnitude of the unit values between treatment and control parcels for each statistically significant component of SSC #4.1.

2.2. Assumptions

- Appraised values can be used to show the relative economic merit of all parcels in Harris County.

- The impacts of physical characteristics are the same between parcels of relatively

equal size.

2.3. Hypotheses

2.3.1. Overall Model

- The appraised unit value of parcels categorized as inappropriate to develop or restore (control group) by SSC #1 is significantly lower than the ones which are deemed land appropriate for development/restoration (treatment group) by the same criteria.
- The appraised unit value of the parcels categorized as brownfield (treatment group) by the SSC #3 is higher than those not categorized as brownfield (control group).
- The appraised unit value of parcels which satisfy the conditions for the SSC #4.1 (treatment group) is higher than those which are failed to the SSC #4.1.

2.3.2. Public Transportation Access Model

- The appraised unit value of parcels with centroids within one quarter-mile of at least one bus stop of more than one bus line (treatment group) is higher than those which fail to satisfy (control group) the same criteria.
- The appraised unit value of parcels with centroids within one half-mile of a light rail station (treatment group) is higher than those which fail to satisfy (control group) the same criteria.

2.4. Model Statement

2.4.1. Overall Model

The dependent variable, Unit Value in $/ft^2, can be predicted by the independent variables (SSC #1, #3, and #4.1) as shown in Equation 2.1.

$$UV = B_0 + B_1 \cdot ACRE + C_1 \cdot SSC1 + C_3 \cdot SSC3 + C_4 \cdot SSC4 \qquad \text{Equation 2.1}$$

- UV : Unit Value of the Parcel

- B_0 : Constant

- B_1 : Slope for ACRE

- C_1 : Slope for SSC1

- C_3 : Slope for SSC2

- C_4 : Slope for SSC3

- ACRE : Parcel Size (Acre)

- SSC1 : SSC #1

  · 0: does not meet criteria, 1: meets criteria

- SSC3 : SSC #3

  · 0: does not meet criteria, 1: meets criteria

- SSC4 : SSC #4.1

  · 0: does not meet criteria, 1: meets criteria

2.4.2. Public Transportation Access Model

The dependent variable, Unit Value in $/SF, can be predicted for PTA, SSC#4.1, by a set of independent variables made up of the components that describe that SSC.

$$UV = UV = B_0 + B_1 \cdot ACRE + C_R \cdot R + C_B \cdot B \qquad \text{Equation 2.2}$$

- UV : Unit Value of the Parcel

- B_0 : Constant

- B_1 : Slope for ACRE

- C_R : Slope for R

- C_B : Slope for B

- ACRE : Parcel Size (Acre)

- R : Light Rail Stations

  - 0: fail to have at least one light rail station, 1: parcel to have at least one light rail station within 1/2 mile

- B : Bus Stops

  - 0: fail to have at least one stop for at least two bus lines useable within 1/4 mile, 1: parcel to have at least one stop for at least two bus lines useable within 1/4 mile

2.5. Delimitation

- The population of interest is limited to unimproved parcels within the city limits of

Houston and within a perimeter established one mile outside the Sam Houston

Expressway.

- Only the main effects of the independent variables are considered.

- Tax exempt properties are not included.

CHAPTER III

DATA COLLECTION AND MANAGEMENT

In this chapter, the way to collect and manage data for the statistical analysis will be explained through two sections. The first section is for the retrieved data and the other is for the created data. For collecting data, GIS files that were retrieved from several sources were used. With these retrieved data, new GIS files were created to form new substantial data.

GIS is the system to capture, retrieve, store, create, analyze, manage, and display data which has spatial and attribute information. Normally, the spatial data shows the location and shape of data using vector and raster data on the layer. Vector data consists of points, polylines, and polygons. Raster data is a kind of digital image which contains information within a grid. The powerful function of the GIS is the overlay. With this function, the user can produce new data layers by the combination of various kinds of existing data use of the powerful analysis tools within GIS applications.

In this study, ArcGIS 9.2 was used to create new data for statistical analysis. The main sources which provided useful GIS data are the Houston-Galveston Area Council (H-GAC), Harris County Appraisal District (HCAD), and Harris County Public Infrastructure Department. All files without raster data were created as a format "shapefile" on "GCS North America 1983" coordinate system. For reference, the observational unit in this research is a parcel.

3.1.   Retrieved Data

3.1.1.   Parcels

This is data regarding all parcels within Harris County by HCAD (Harris County Appraisal District, 2009) as shown in FIGURE 3.1 and contains addresses and account numbers of each parcel as attribute data. For reference, this is updated every quarter of a year and the data used in this research is for the first quarter of 2009.
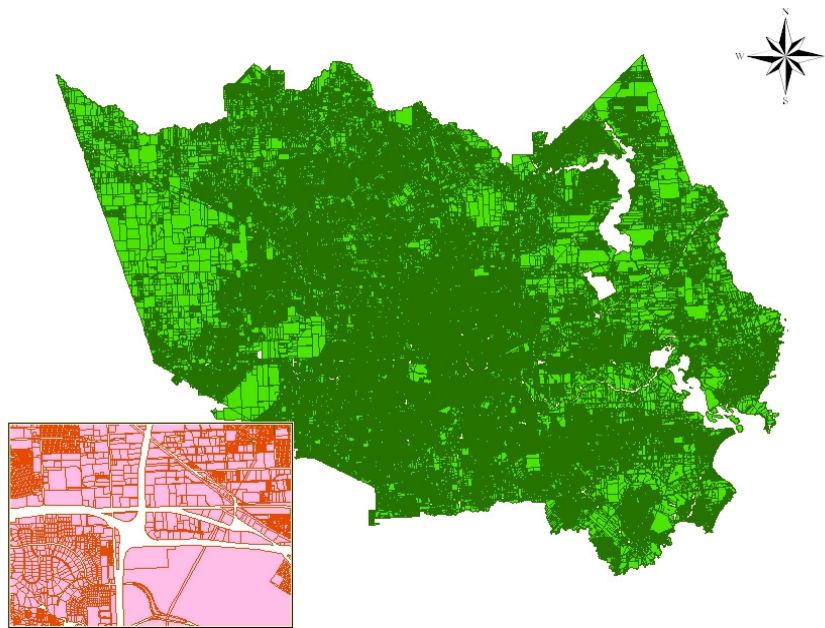
FIGURE 3.1 Parcel within Harris County

3.1.2.   Refuges

This file has the spatial and attribute data regarding the refuges of endangered wildlife in Texas. For reference, there is no refuge around/within Houston.

3.1.3.   Roads

This file (Houston-Galveston Area Council, 2008) contains major roads in Harris County with polylines.

3.1.4.   Limits and Regions

These files (Harris County Public Infrastructure Department, 2008) have a spatial data of Houston and Harris County, respectively.

3.1.5.   Land Use and Cover

H-GAC produced a raster file regarding land use/cover of H-GAC region. This file (Houston-Galveston Area Council, 2009) contains spatial and attribute data for land use/cover with ten categories: cultivated land, wetland, forest, barren, grass land, open water, and so on.

3.1.6.   Wetlands

This file is for the wetland in H-GAC regions. The spatial data is the shape and location of wetlands. The attribute data contains the type of wetlands. In this research, all types of wetlands which satisfy the conditions regarding SSC #1 were considered.

3.1.7.   Floodable Lands

This file (Harris County Public Infrastructure Department, 2008), which has spatial data to display 100-year flood planes in the City of Houston, was made by FEMA.

3.1.8.   Parks

These files (Houston-Galveston Area Council, 2009) contain the spatial and attribute data for national, state, and local parks in H-GAC. In FIGURE 3.2, the red means local parks and the blue shows state parks in the City of Houston. For reference, there is no national park in the target area.
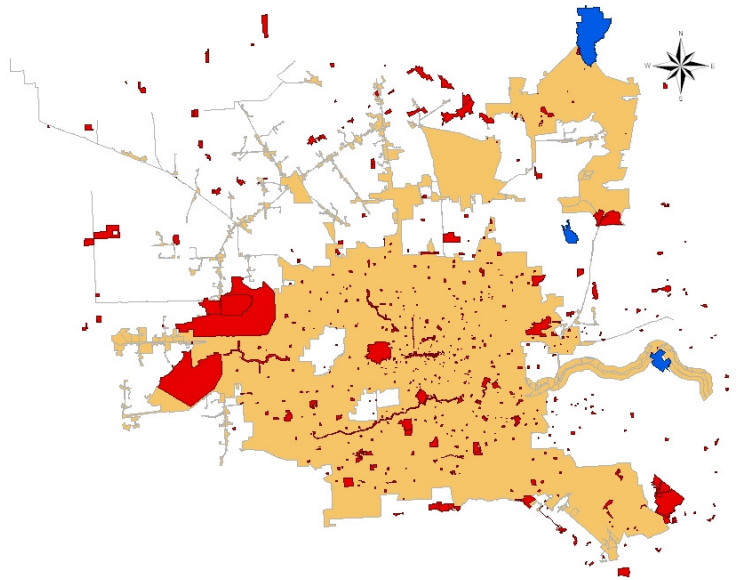
FIGURE 3.2 Parks in the City of Houston

3.1.9.   Water Bodies

This file (Harris County Public Infrastructure Department, 2008) is for the water bodies in H-GAC regions. The spatial data is the shape and location of the water bodies. The attribute data contains the type of water bodies. In this research, all types of water bodies which satisfy the conditions regarding SSC #1 were considered.

3.1.10.   Bus Stops

These files (Houston-Galveston Area Council, 2009) contain the spatial and

attribute data for bus stops and bus routes in H-GAC. Among the bus stops in the City of

Houston, some are out of service. Thus, it is required to select in-service bus stops from

the attribute table.

3.1.11.   Light Rail Stations

These files (Houston-Galveston Area Council, 2009) contain the spatial and

attribute data for the light rail stations and its routes in H-GAC region. In addition to this

existing line, there are two more lines approved for construction. According to LEED

credit rules, lines under construction are to be considered. However, in this study, the

information regarding future stations was not used due to the non-availability of GIS

data and the likelihood of changes.

3.2.   Created Data

All new shapefiles introduced in this section are created on the coordinate system

of "GCS North America 1983" using retrieved data which were explained in the

previous section. The main purpose of this procedure, "Creating New Shapefiles", is

basically to extract parcels which are qualified according to SSC criteria and eventually

to produce new shapefiles with extracted polygons to express these qualified parcels.

Besides these spatial data, among the attribute data to be arranged, the field "Account"

contains the account number of all extracted parcels, and it will be used as the common

point to be correlated with the other data of the parcel. A brief description of these

created shapefiles is summarized as shown in TABLE 3.1.

TABLE 3.1 Summary of Created Data

ID	Files	Contents
1	"target_parcel.shp"	Parcels within the target area
2	"failure_ssc_1_parcel.shp"	Parcels failed to the SSC #1
3	"success_ssc_3_parcel.shp"	Parcels qualified to the SSC #3
4	"success_ssc_4_parcel.shp"	Parcels qualified to the SSC #4.1
5	"bus_parcel.shp"	Parcels qualified to the bus stop conditions
6	"rail_parcel.shp"	Parcels qualified to the rail station condition

3.2.1.   Parcels in the Target Area

3.2.1.1. Description

This file shows spatial data for the population of interest in the target area. The

target area is the part of the City of Houston within a circumference bounded a mile

outside Beltway 8 as shown in FIGURE 3.3. The green line represents the circumference

of the target area. In this file, the information for the parcels was saved as a polygon type.

3.2.1.2. Procedure

- STEP #1: Make a new file *"beltway.shp"* which contains a poly-line delineating

  Beltway 8 expressway within Harris County. This poly-line can be extracted

  selectively from all poly-lines to symbolize roads in Texas among retrieved data.

- STEP #2: With a buffer function, create a new file *"away_beltway.shp"* which has

  a poly-line to show the circumference bounded a mile outside Beltway 8.

- <u>STEP #3</u>: Clip a part of a polygon which indicates the region of the City of Houston with a poly-line in a created file *"away_beltway.shp"*, and create a new file *"target_area.shp"* with the clipped polygons. FIGURE 3.4 shows the polygon to express the target area. For reference, the trimmed part is the region outside a poly-line to symbolize the circumference bounded a mile outside Beltway 8.

- <u>STEP #4</u>: Extract polygons to show parcels whose centroids are within polygons to indicate the target area in a created file *"target_area.shp"* from a retrieved data regarding parcels in Harris County, and complete a new file *"target_parcel.shp"* to contain polygons for parcels within the target area with extracted polygons as shown in FIGURE 3.5.
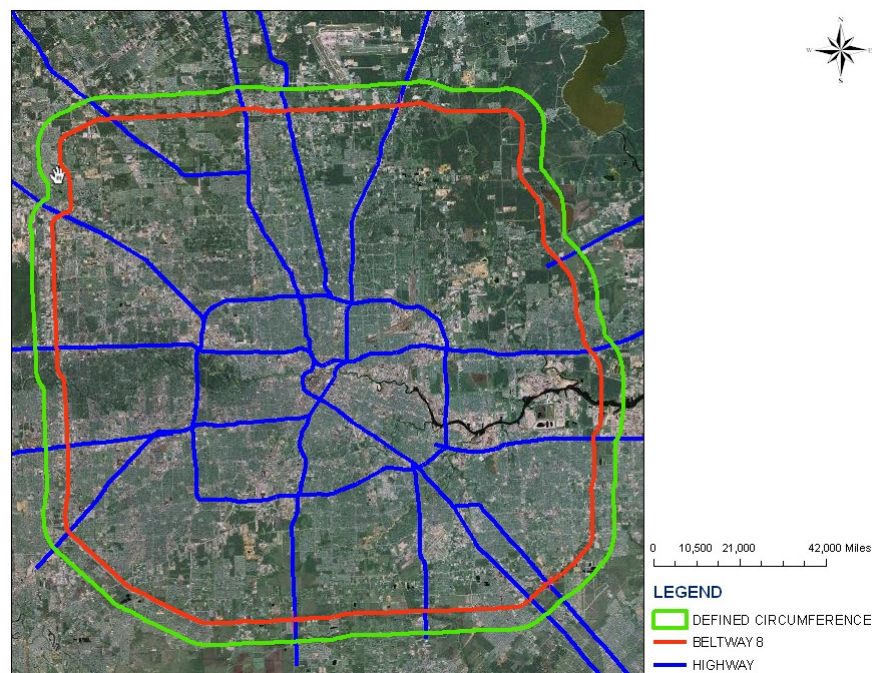
FIGURE 3.3 The Satellite Image for the Target Area
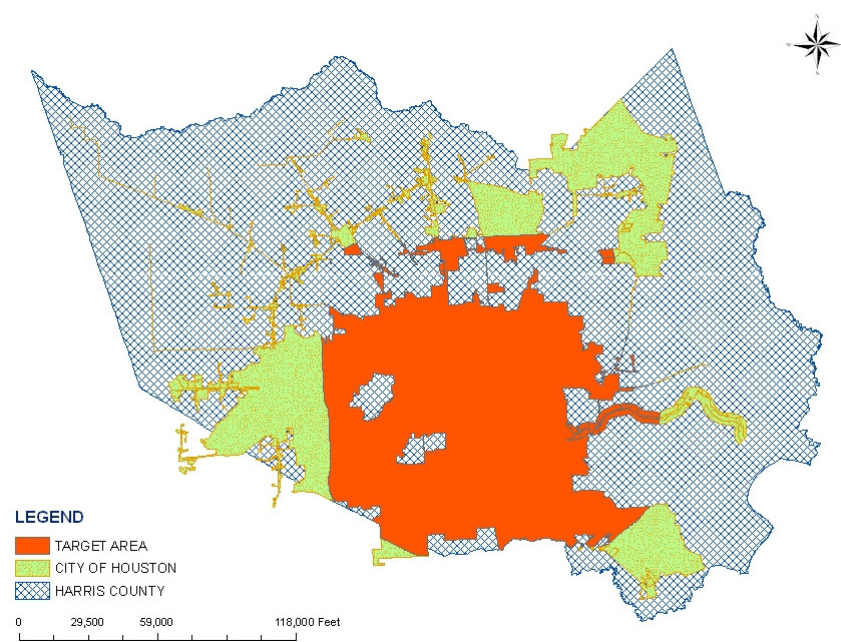
FIGURE 3.4 Polygons for the Target Area
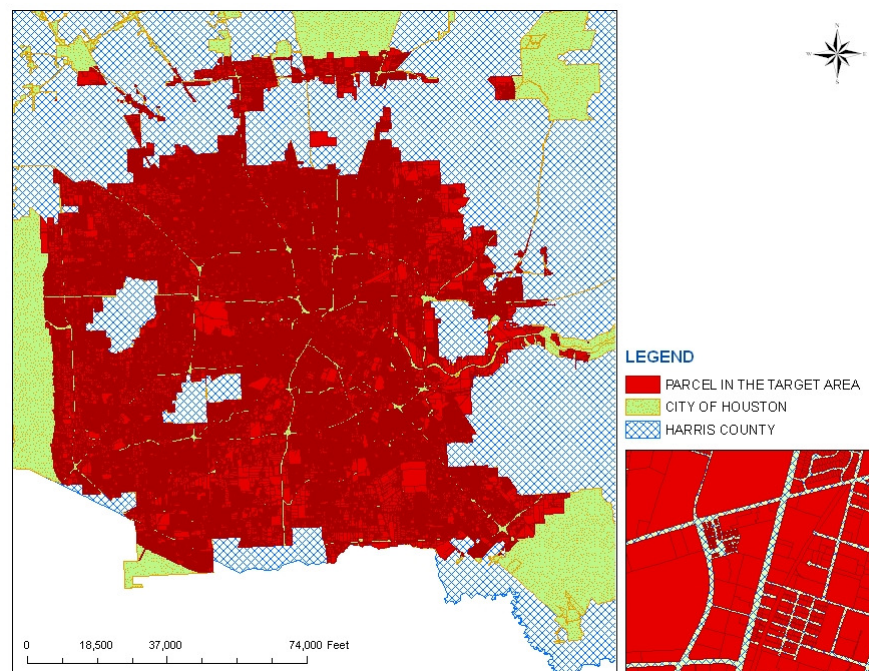
FIGURE 3.5 Parcels in the Target Area

3.2.2.   Parcels Failed to the SSC #1

3.2.2.1. Description

The spatial data in this file are polygons that indicate parcels which are inappropriate lands to develop or restore in terms of sustainable credit criteria #1 (Site Selection) within the target area. The essential attribute data required in this process is the account number of extracted parcels.

3.2.2.2. Procedure

- STEP #1: Extract all polygons to express prime farmlands in a retrieved raster data *"hg_lulc.img"* and make a new shapefile *"prime_farmland.shp"* which contains the polygons to symbolize all prime farmlands in H-GAC region.

- STEP #2: Extract all 100-year floodable lands in a retrieved shapefile *"100_year_flood_land.shp"* and calculate the elevation of each extracted lands with a retrieved raster data *"hg_dem.img"* to contain the elevation of the H-GAC region. Then digitize all lands which are lower than 5 feet above the calculated elevation with a raster data *"hg_dem.img"* and convert the digitized regions with polygons of a new shapefile *"foodable_land.shp"*.

- STEP #3: Merge all polygons which express national, state, and local parks in retrieved shapefiles *"tx_national_park.shp"*, *"tx_state_ park.shp"*, and *"local_park.shp"*, respectively, and create a new shapefile *"park_land.shp"* which has polygons to indicate national and state parks in Texas and local parks in the H-GAC region.

- STEP #4: Merge all polygons which are in created files *"prime_farmland.shp"*, *"floodable_land.shp"*, *"park_land.shp"*, and the retrieved files *"texas_refuge.shp"*, *"hg_wetland.shp"*, and *"harris_waterbody.shp"* in the previous section. Then create a new file *"failure_ssc_1_area.shp"*.

For reference, there are no refuges for endangered wildlife, prime farmlands, or national parks in the target area. FIGURE 3.6 shows inappropriate land to develop or restore in terms of the SSC #1.

- STEP #5: Among all the parcels in a file *"target_parcel.shp"*, extract parcels whose centroids are within the polygons to express lands to avoid development/restoration in a file *"failure_ssc_1_area.shp"*.
- STEP #6: Complete to create a file *"failure_ssc_1_parcel.shp"* with extracted parcels in step #5. In this file, polygons, as shown in FIGURE 3.7, indicate the parcels in which land development/restoration is discouraged.
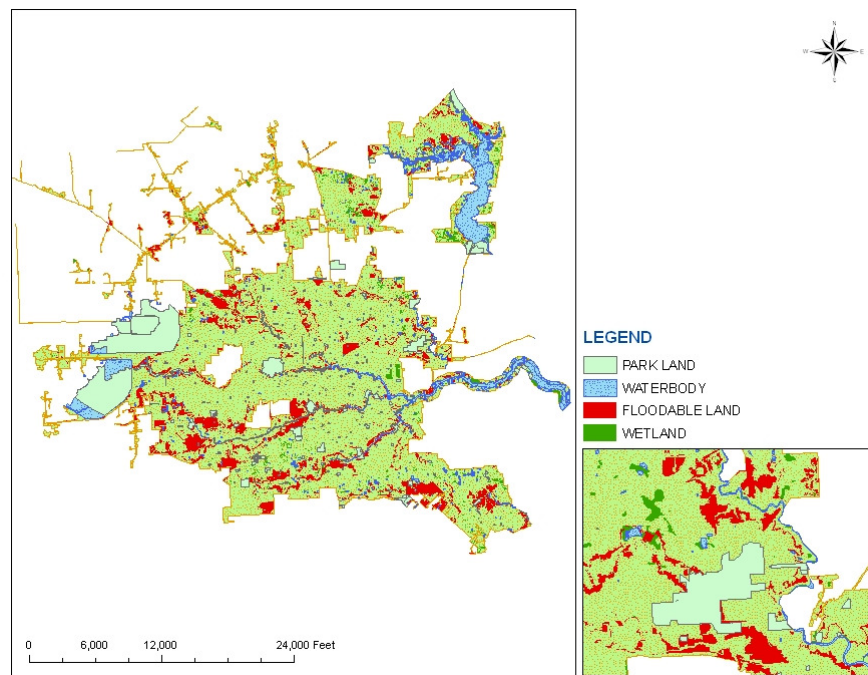
FIGURE 3.6 Disqualified Lands to the SSC #1
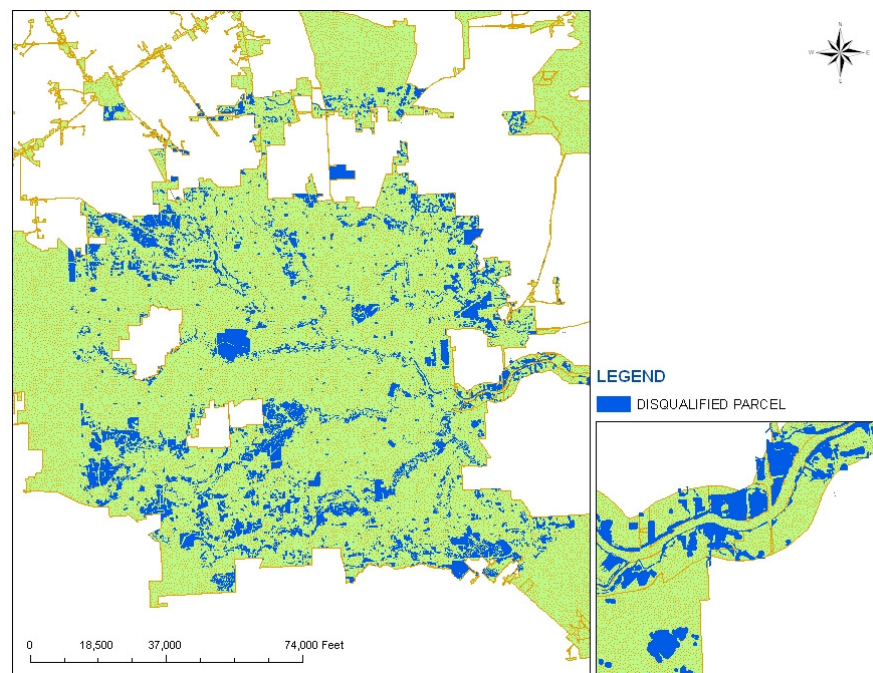
FIGURE 3.7 Disqualified Parcels to the SSC #1

3.2.3.   Qualified Parcels to the SSC #3

3.2.3.1. Description

   This file contains the polygon to express the parcels which are qualified

according to SSC #3 as spatial data.

3.2.3.2. Procedure

- STEP #1: Geo-reference (Register) the map for brownfield parcels in Houston

    with the road map in a graphic file *"brownfield.jpg"* according to the poly-lines

    expressing major roads in a file, *"texas_road.shp"*.

- STEP #2: Digitize features to indicate the brownfield of the map *"brownfield.jpg"*

    with polygons to express these features on a new file,

    "houston_brownfield_area.shp".

- STEP #3: Extract parcels whose centroids are within the polygons to symbolize the

    brownfields in the created file *"houston_brownfield_area.shp"* from the created

    file "target_parcel.shp" and then create a new file, *"success_ssc_3_parcel.shp"*.

   FIGURE 3.8 shows the polygons to express brownfields in a file,

"houston_brownfield_parcel.shp".
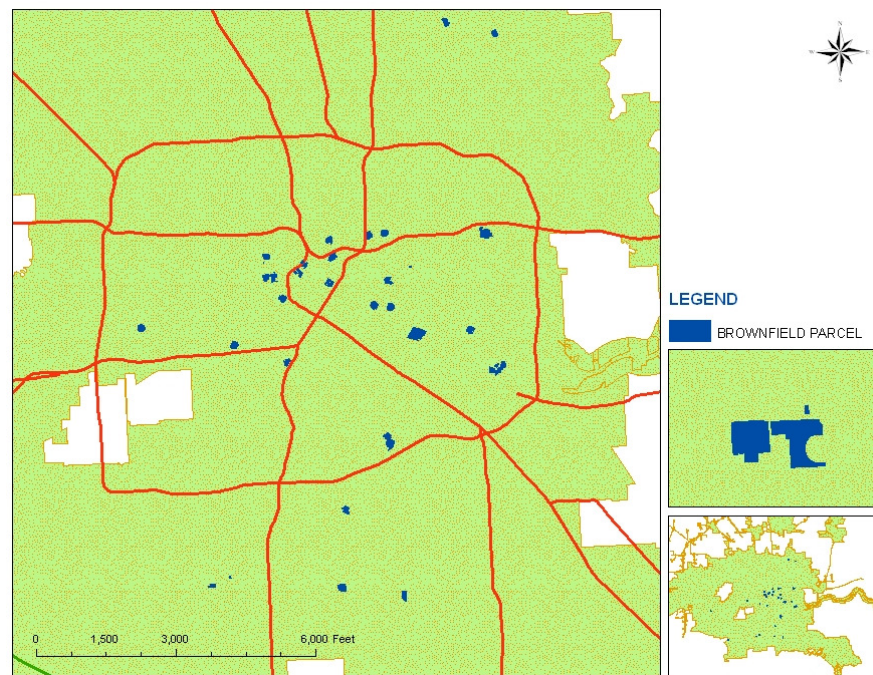
FIGURE 3.8 Qualified Parcels to the SSC #3

3.2.4. Qualified Parcel to the SSC #4.1

3.2.4.1. Description

In this file, polygons express parcels whose centroids are within the areas which are qualified for SSC criteria #4. Thus, the spatial data are polygons representing parcels whose centroids are qualified for these criteria. The attribute data is the account number for each qualified parcel.

3.2.4.2. Procedure

- STEP #1: Extract points to symbolized in-service bus stops in a retrieved data and create a file, *"metro_in_service_busstop.shp"* with the extracted points.

- STEP #2: Extract parcels whose centroid is within a quarter mile of points to

express in-service bus stops in file, *"metro_in_service_busstop.shp"* and create a
file *"busstop_in_parcel.shp"*.

- STEP #3: Merge polygons to express parcels in a file *"busstop_in_parcel.shp"*
  with points to indicate bus stops in a file, *"metro_in_service_bus_stop.shp"*, and
  create a file, *"busstop_with_parcel.shp"*.

- STEP #4: Extract polygons to express parcels which have bus stops for two or
  more useable lines from a file *"busstop_with_parcel.shp"* and create a file
  "bus_parcel.shp". FIGURE 3.9 shows the parcel to be qualified to meet the
  conditions of the SSC #4.1 regarding the bus stops.
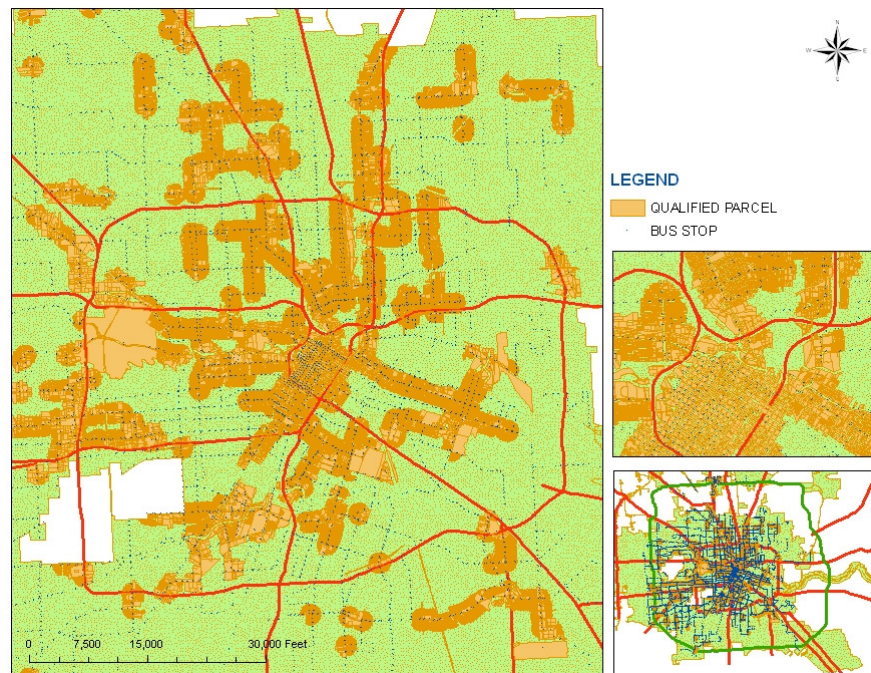
FIGURE 3.9 Qualified Parcels to the Bus Conditions of SSC #4.1

- STEP #5: Extract parcels with centroids within a half mile from points that

symbolize metro light-train stations in a retrieved data from a data in file

"target_parcel.shp" and create a file *"train_parcel.shp"*. FIGURE 3.10 shows

the polygon to indicate parcels qualified for the SSC #4.1 regarding the train

stations.
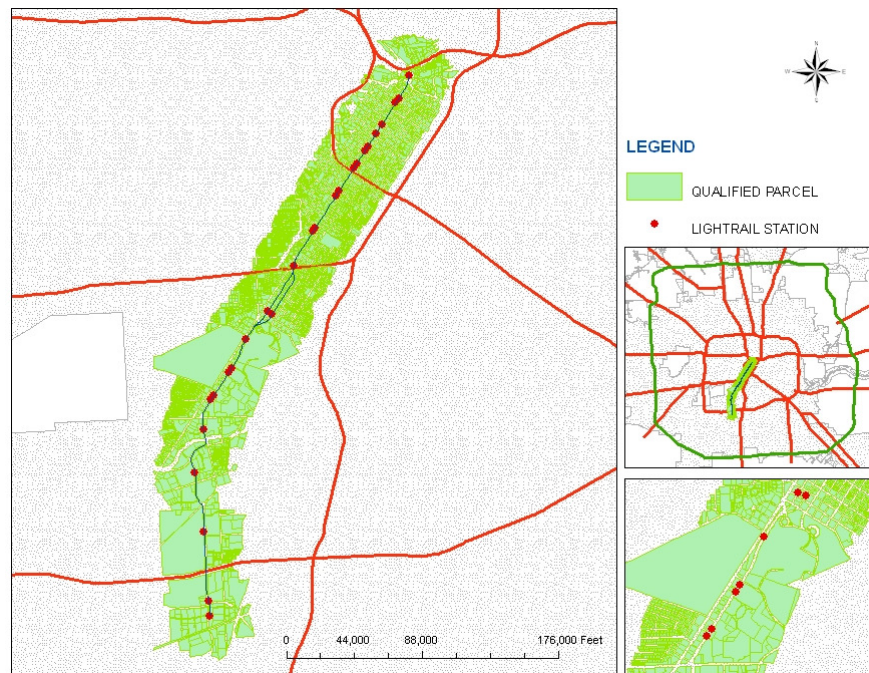
FIGURE 3.10 Qualified Parcels to the Rail Conditions of SSC #4.1

- STEP #6: Merge a file *"bus_parcel.shp"* with a file *"train_parcel.shp"* and

  create a new file *"success_ssc_4_parcel.shp"*. In this file, polygons express

  parcels qualified for SSC #4.1, and the attribute data contains the parcel account

  number. FIGURE 3.11 shows the parcels qualified to meet the conditions of

  PTA.
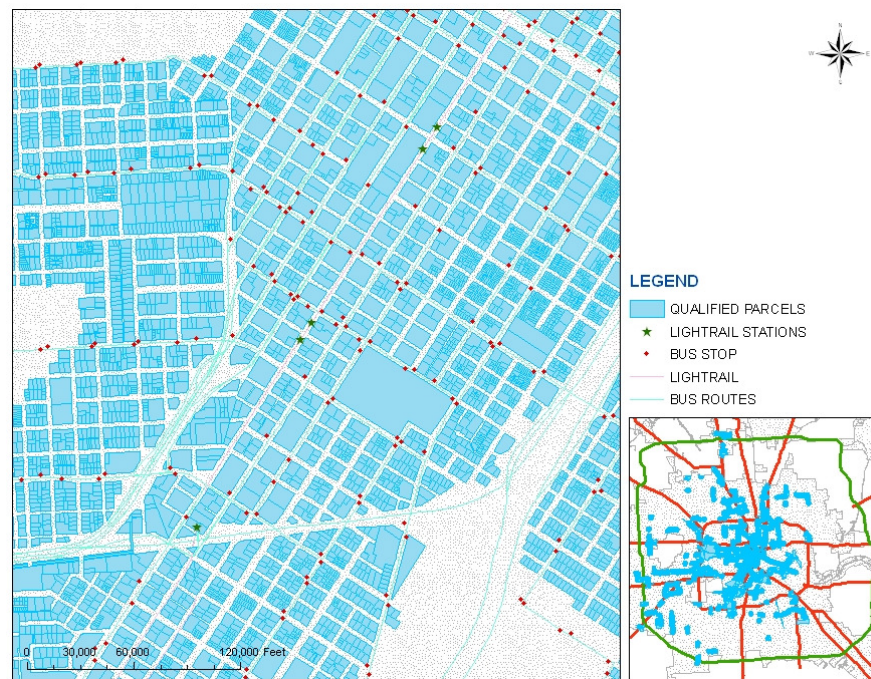
FIGURE 3.11 Qualified Parcels to the SSC #4.1

3.3. Population of Interest

3.3.1. Overall Model

The population of interest consists of the land parcels within the city limits of Houston located within/around Beltway 8: bounded by a line one mile outside Beltway 8. Additionally, the parcel must be private land and its improved value is appraised at zero dollars (not exempt from property tax)

3.3.1.1. SSC #1

As a treatment group, all unimproved parcels in which development is discouraged according to LEED metrics in the target area, while control group is constituted with parcels which do not belong to the treatment group and whose centroids are within 500 feet from the each centroid of all parcels of the treatment group.

3.3.1.2. SSC #3

As a treatment group, all parcels which indicate (in part or whole) brownfield within the target area, while control group is constituted with all parcels which do not belong to the treatment group and whose centroids are within 500 feet from the centroid of all parcels of the treatment group.

3.3.1.3. SSC #4.1

As a treatment group, all parcels which have commuter rail, light rail, or a subway station within ½ mile of their centroid or which have at least one stop for at least

two bus lines useable within ¼ mile of their centroid and within the target area. On the

contrary, a control group is constituted with all parcels which do not belong to the

treatment group and whose centroids are within 500 feet from the centroid of all parcels

of the treatment group.

3.4. Sample Selection

3.4.1. Limitations

- The sales price is one of the best objective values in order to express the economic

  worth of the land, but in Texas it is difficult if not impossible to obtain.

- The appraised land value per square foot ($/ft^2) is employed as a response variable

  in the regression model because this value is regularly assessed by the local

  appraisal district and is public information.

- There are many factors that may affect land values, but the components regarding

  SSCs are the matter of main concern in this research along with the size of each

  parcel.

- Public parcels, churches, etc. will be excluded because there is no assessed value

  required since they are tax exempt.

- Samples for the overall model will be combined with samples which are selected

  from populations of each SSC. This technique is used rather than a complete

  random sample because it is not easy to obtain parcels which are qualified in each

  SSC.

3.4.2. Public Transportation Access Model

In each SSC group, there are two subgroups: the treatment and control group. In the SSC-1 treatment group, sampled parcels, which would be required to qualify for their associated site score credit, are chosen randomly among the parcels of the population. In control groups, parcels will be non-randomly selected from a qualified set of parcels paired to a member of the treatment group. The qualifying characteristics will include the distance from the treatment property (no more than 500 feet from centroid to centroid), size relative to the treatment property, and failure to qualify for the site score credit of the treatment parcel. Each treatment and control subgroup will consist of 100 parcels. Therefore, there will be 200 paired parcels for the criteria in this sample.

3.4.3. Overall Model

The sample for the overall model will be formed by combining all the groups selected for models of the SSC #1, SSC #3, and SSC #4.1. For reference, each group has two subgroups: treatment and control group. The number of parcels in the overall model will approach but not exceed 600 because of a few duplicated parcels.

CHAPTER IV

ANALYSIS, RESULTS, AND INTERPRETATION

The main purpose of this chapter is to suggest linear regression models that predict the unit appraised value ($/ft^2) of unimproved and private parcels in the City of Houston, Texas, using regression analysis and to investigate the effect of each independent variable used in this research. To achieve this, it is necessary to examine properties of each variable to be analyzed using uni-variate analysis and to identify the relationships between variables used in the predictive models with bi-variate analysis.

In the uni-variate analyses, the data for each complete population will be used. Otherwise, sampled data from each population will be used in a bi- and multi-variate analysis.

4.1.   Uni-Variate

In a uni-variable analysis, preferentially descriptive analysis using various plots will be discussed. Then the tabular results can be analyzed to check the properties of each variable more carefully.

4.1.1.   Plots

4.1.1.1.   Analysis

Descriptive analysis can show critical statistics such as means, medians, and modes for the analysis of each variable. Furthermore, it is also important to scrutinize

the distribution of data such as variances, standard deviations, ranges, and interquantile

ranges. For showing these statistics, it may be effective to draw histograms, Q-Q plots,

and boxplots to see how variables are distributed separately because these plots can

show statistics mentioned above more clearly than tabular results.

4.1.1.2. Results

As mentioned in the previous chapter, the elements in this target population are

all unimproved parcels inside Beltway 8 within the city limits of Houston which do not

have any special tax exempt status.

FIGURES 4.1-4.3 show the histogram, normal quantiles, and the box plot for the

distribution of areas (Acres) of the parcel elements in the target population.

FIGURE 4.1 Histogram of the Population for the Parcel Area
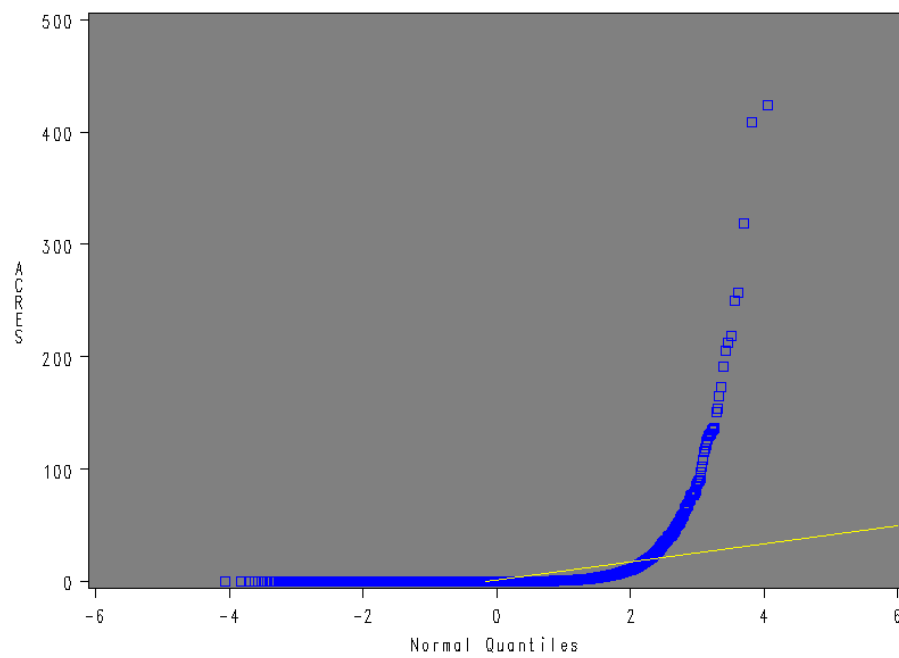
FIGURE 4.2 Normal Quantiles of the Population for the Parcel Area

FIGURE 4.3 Boxplot of the Population for the Parcel Area

FIGURES 4.4-4.6 show the histogram, normal quantiles, and the box plot for the

distribution of appraised value ($) of the parcel elements in this target population.
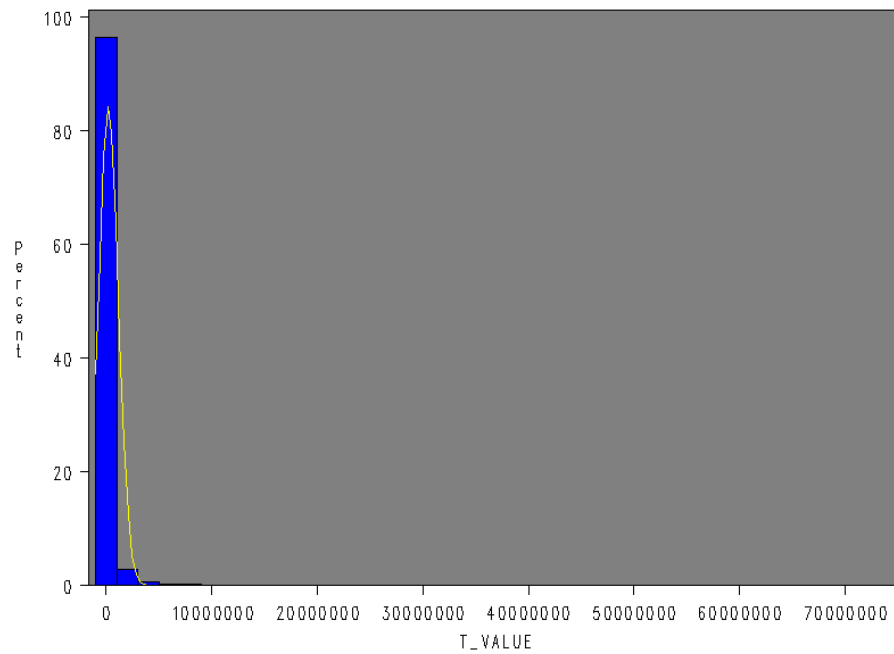
FIGURE 4.4 Histogram of the Population for the Parcel-appraisal Value
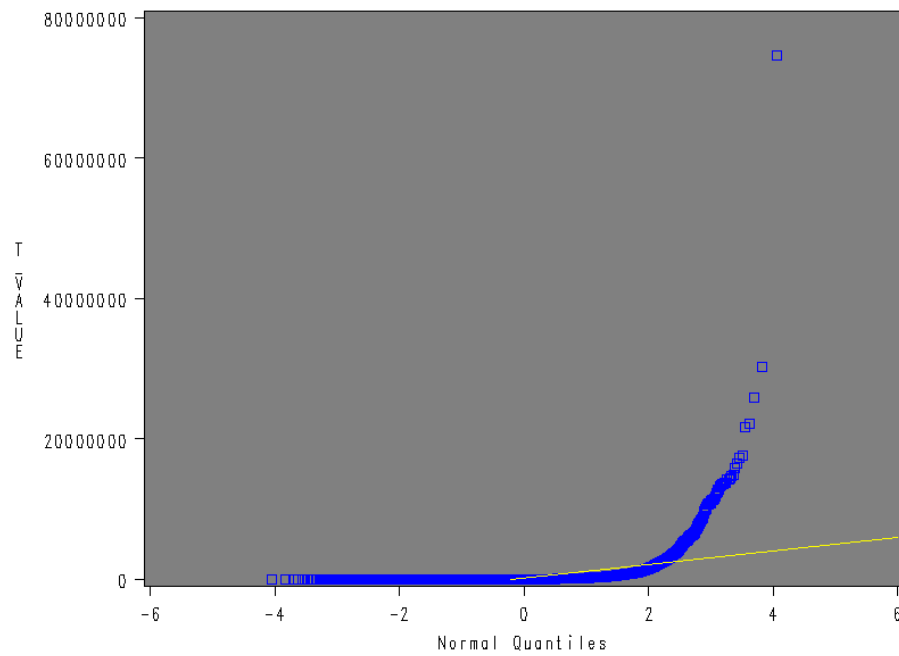
FIGURE 4.5 Normal Quantiles of the Population for the Parcel-appraisal Value
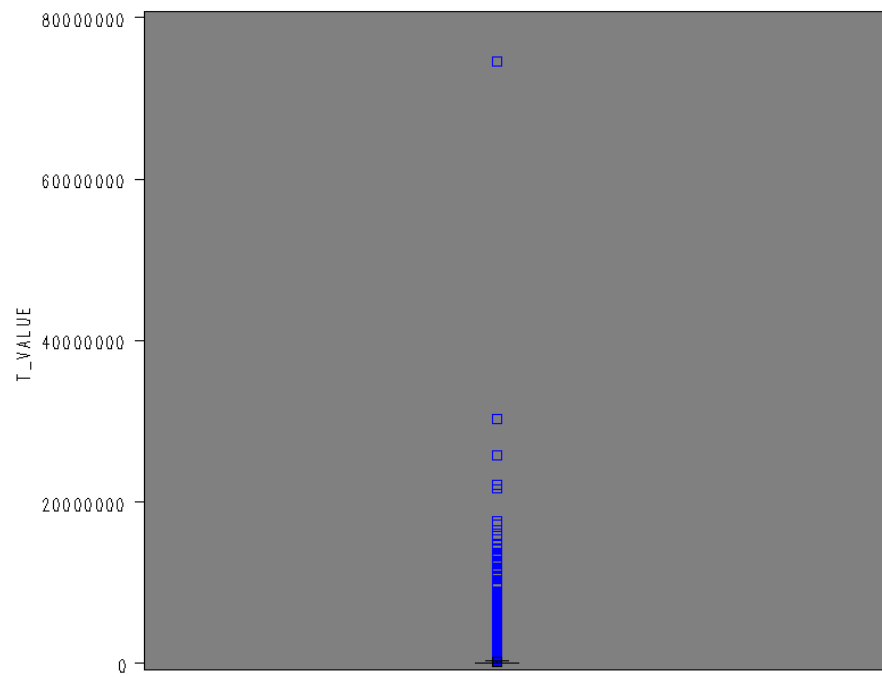
FIGURE 4.6 Boxplot of the Population for the Parcel-appraisal Value

FIGURES 4.7-4.9 show the histogram, normal quantiles, and the box plot for the distribution of unit values ($/ft^2) of parcel elements in the target population.

FIGURE 4.7 Histogram of the Population for the Unit Value of the Parcel
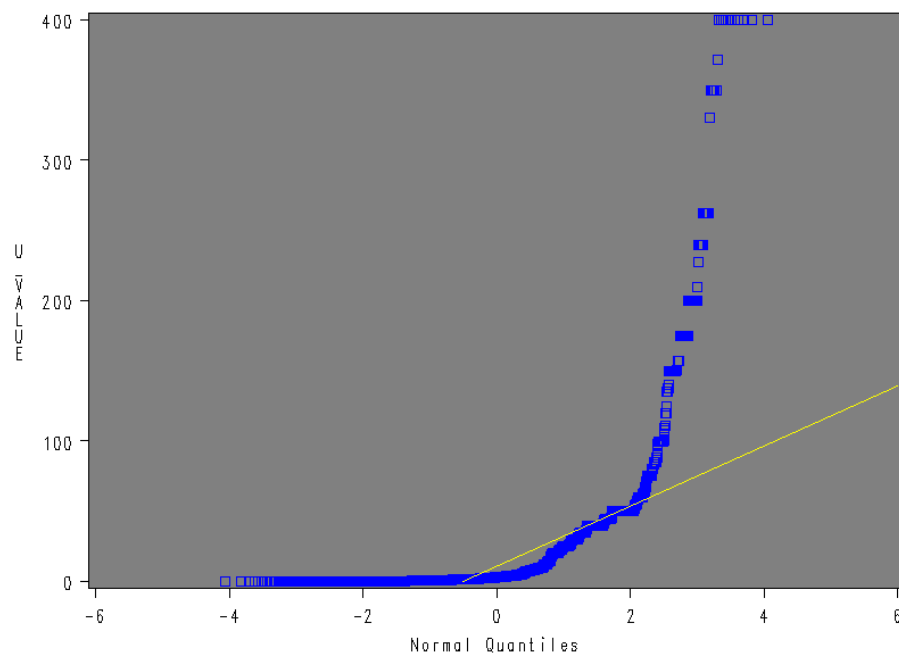
FIGURE 4.8 Normal Quantiles of the Population for the Unit Value of the Parcel
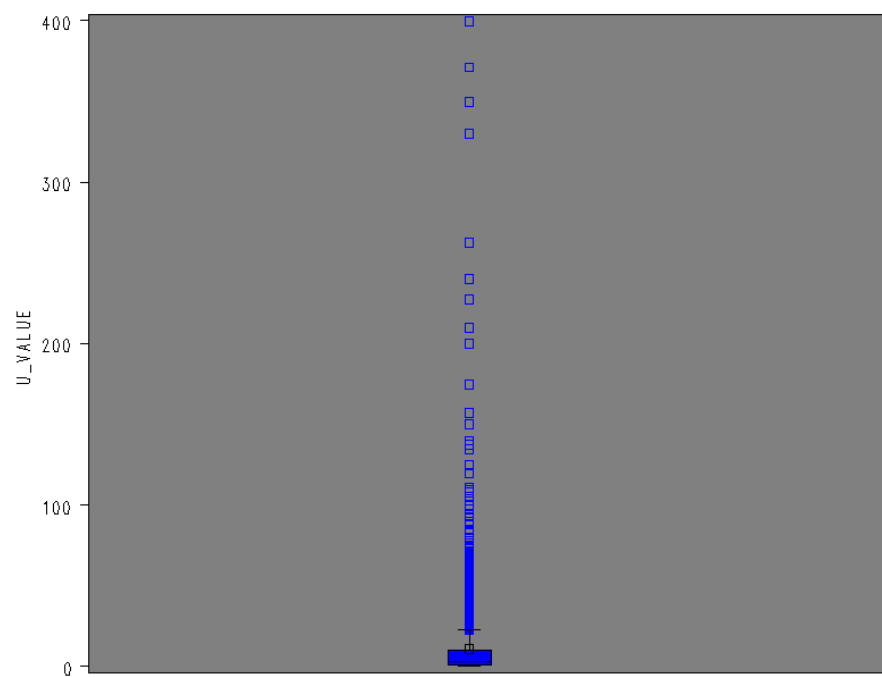
FIGURE 4.9 Boxplot of the Population for the Unit Value of the Parcel

FIGURES 4.10-4.12 show the histogram, normal quantiles, and the box plot for the distribution of unit values ($/ft^2) of the parcel elements in the population for site selection criteria.
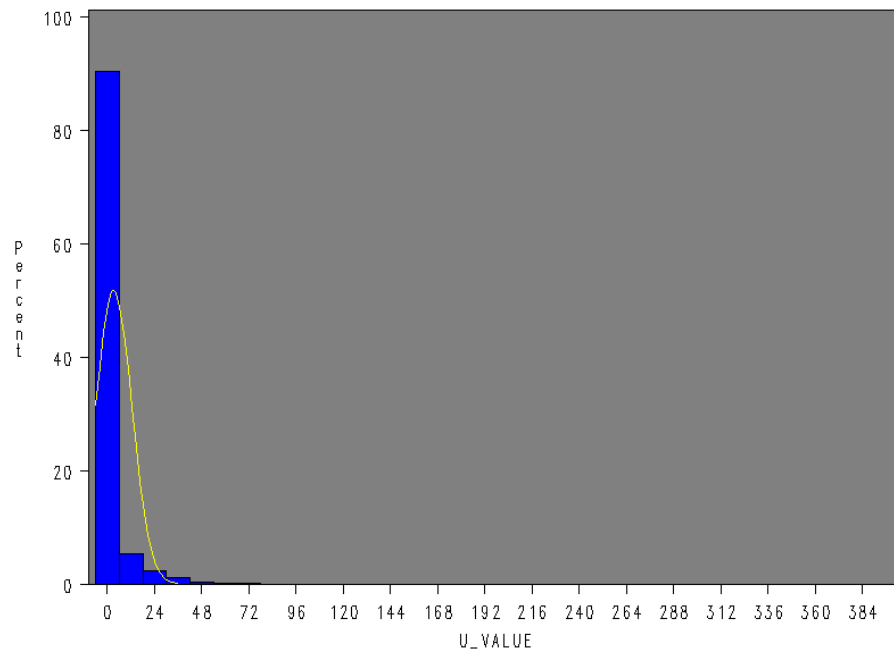
FIGURE 4.10 Histogram for the SSC #1 Population
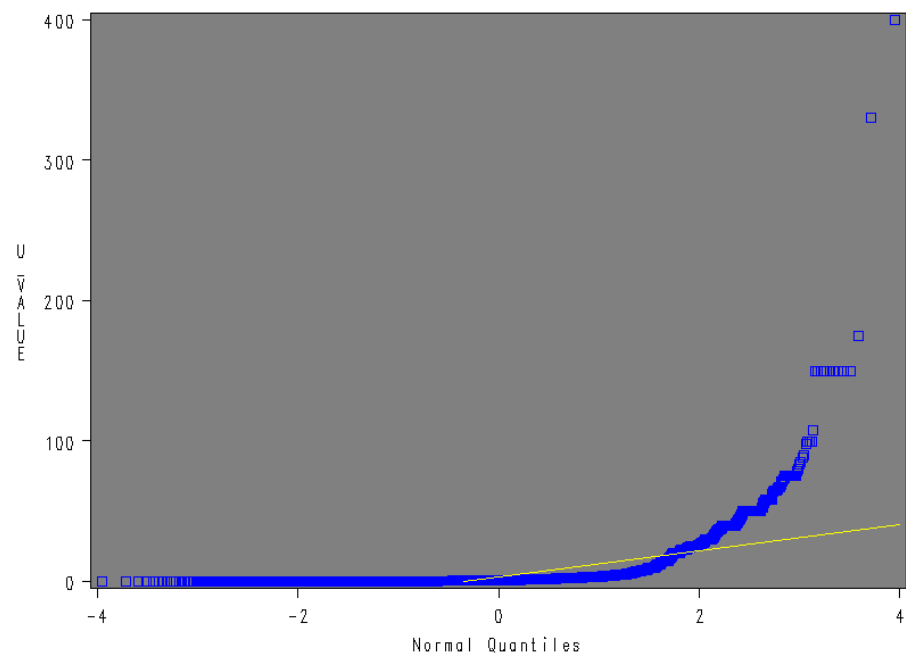
FIGURE 4.11 Normal Quantiles for the SSC #1 Population
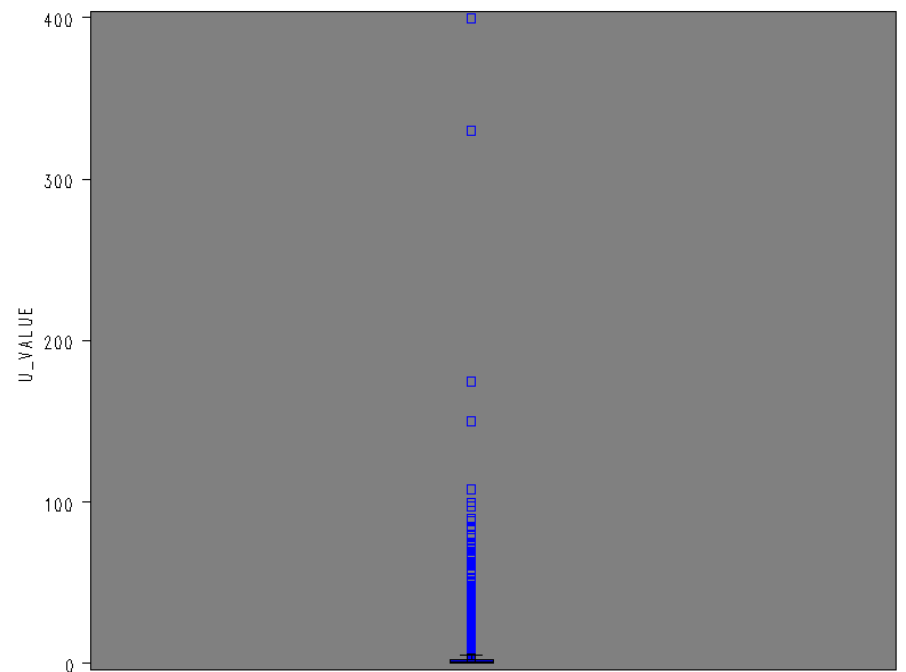
FIGURE 4.12 Boxplot for the SSC #1 Population

FIGURES 4.13-4.15 show the histogram, normal quantiles, and the box plot for the distribution of unit values ($/ft^2) of parcel elements in the population for brownfield criteria.
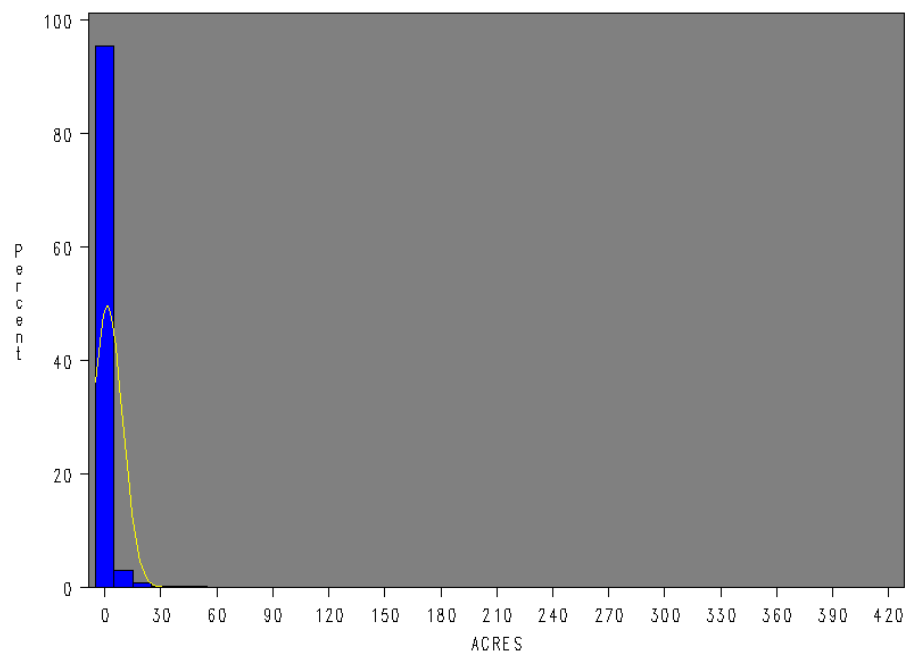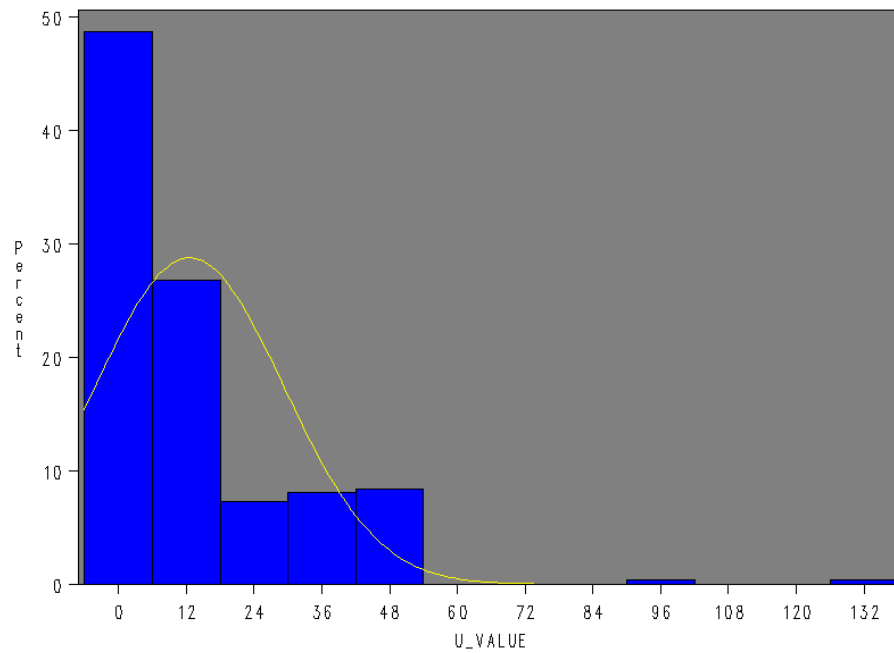
FIGURE 4.13 Histogram for the SSC #3 Population
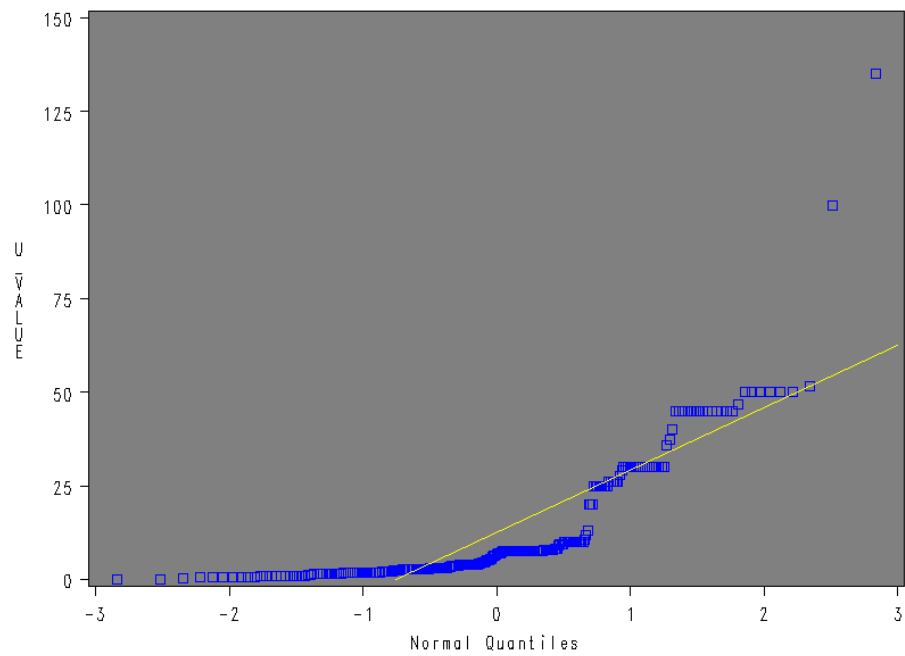
FIGURE 4.14 Normal Quantiles for the SSC #3 Population
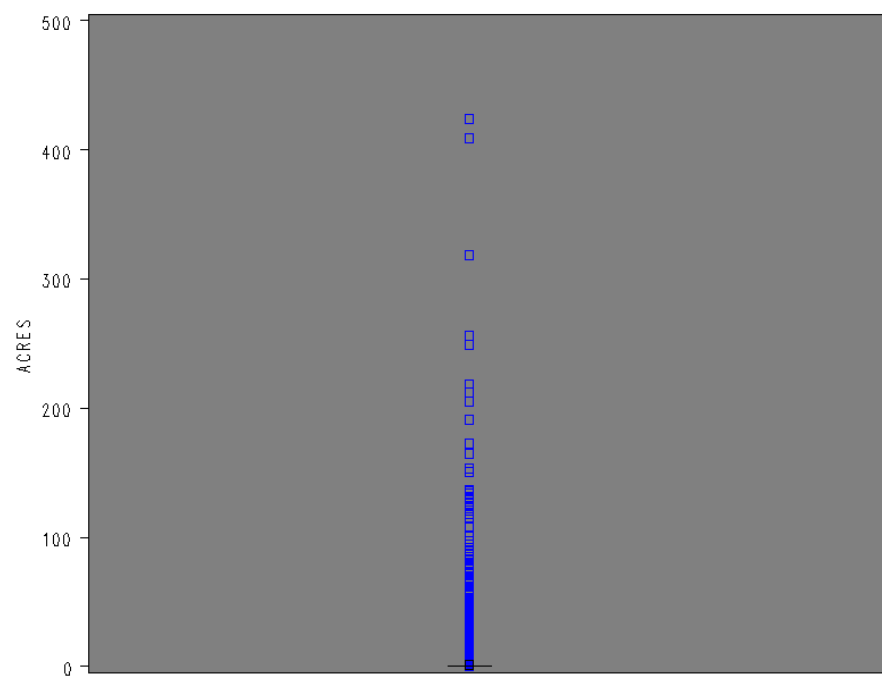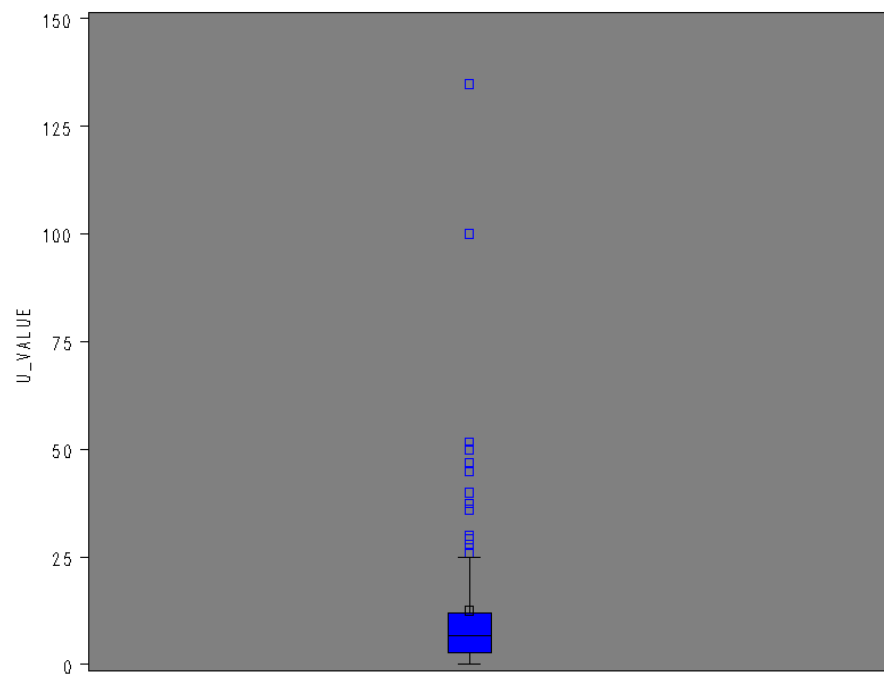

FIGURE 4.15 Boxplot for the SSC #3 Population

FIGURES 4.16-4.18 show the histogram, normal quantiles, and box plot for the

distribution of unit values ($/ft^2) of parcel elements in the population for PTA criteria.
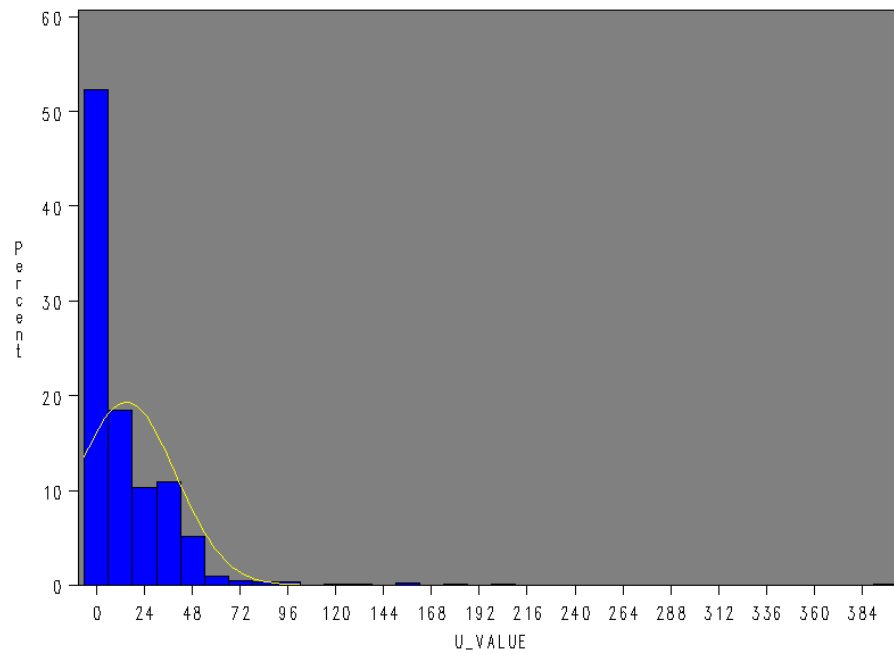
FIGURE 4.16 Histogram for the SSC #4.1 Population
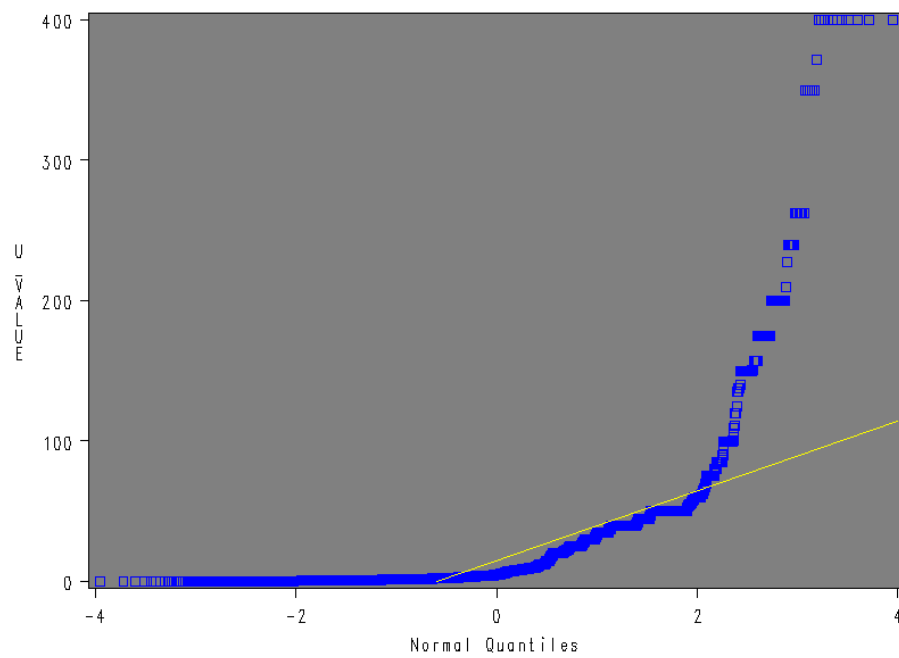
FIGURE 4.17 Normal Quantiles for the SSC #4.1 Population
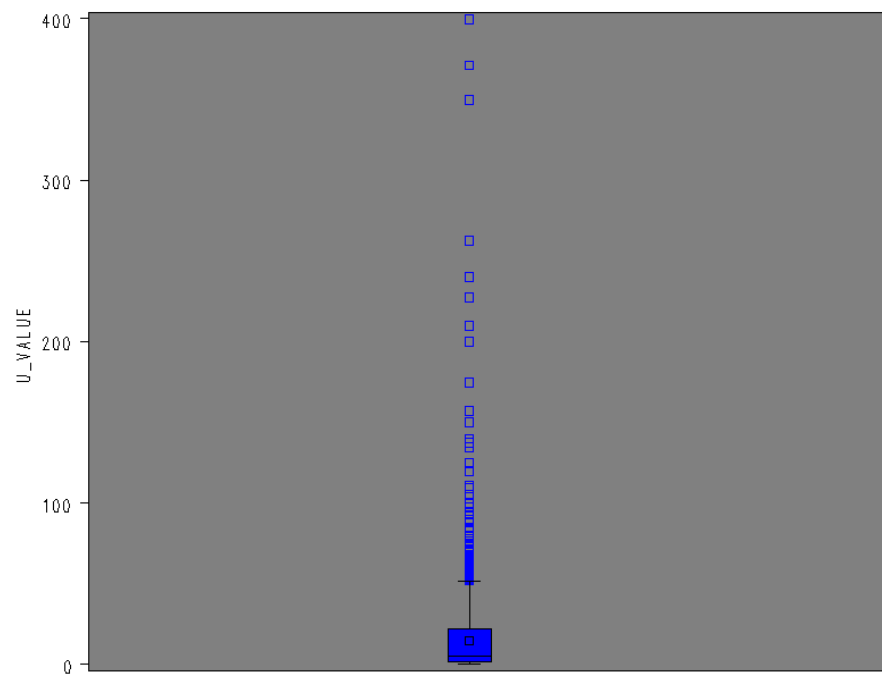
FIGURE 4.18 Boxplot for the SSC #4.1 Population

FIGURES 4.19-4.21 show the histogram, normal quantiles, and box plot for the distribution of unit values ($/ft^2) of parcel elements in the population that meet bus stop conditions of PTA criteria.
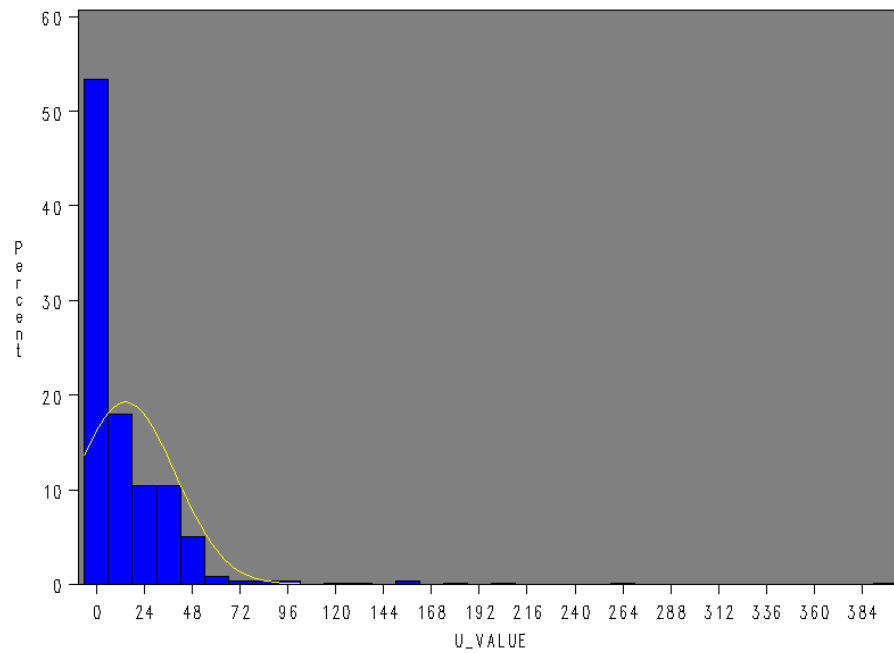

FIGURE 4.19 Histogram for the Bus Stop Conditions of the SSC #4.1
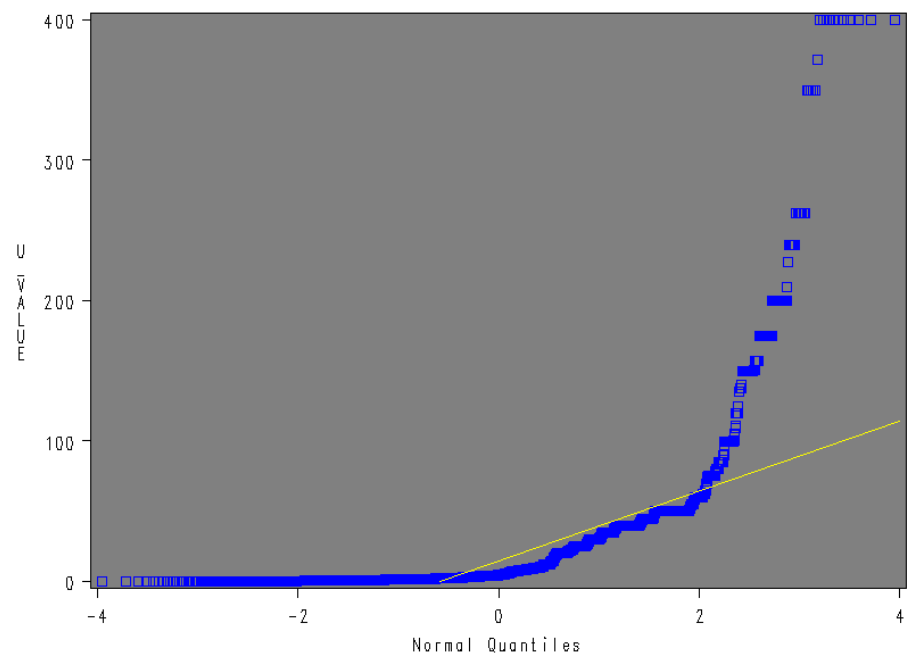
FIGURE 4.20 Normal Quantiles for the Bus Stop Conditions of the SSC #4.1
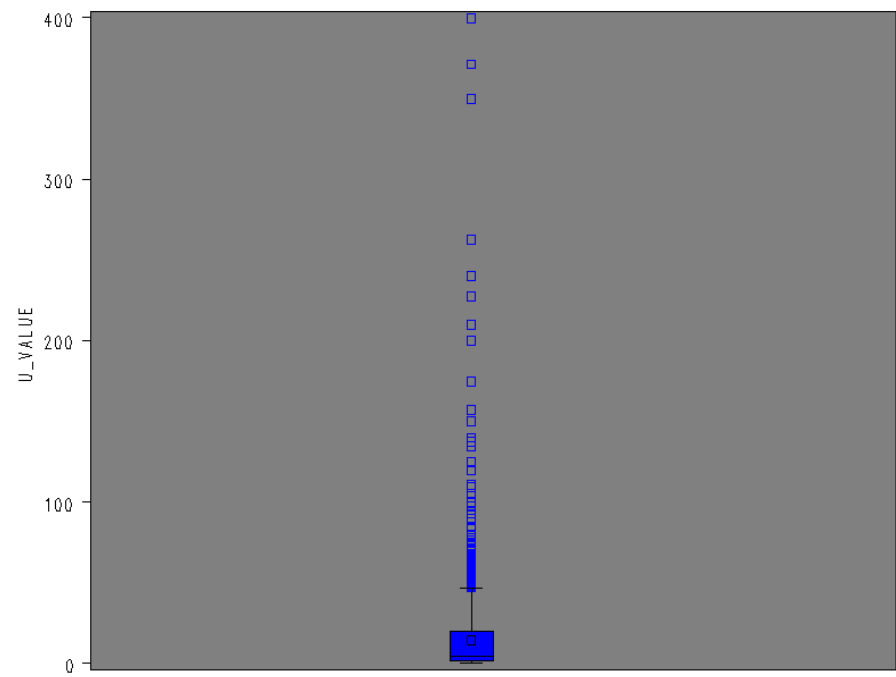
FIGURE 4.21 Boxplot for the Bus Stop Conditions of the SSC #4.1

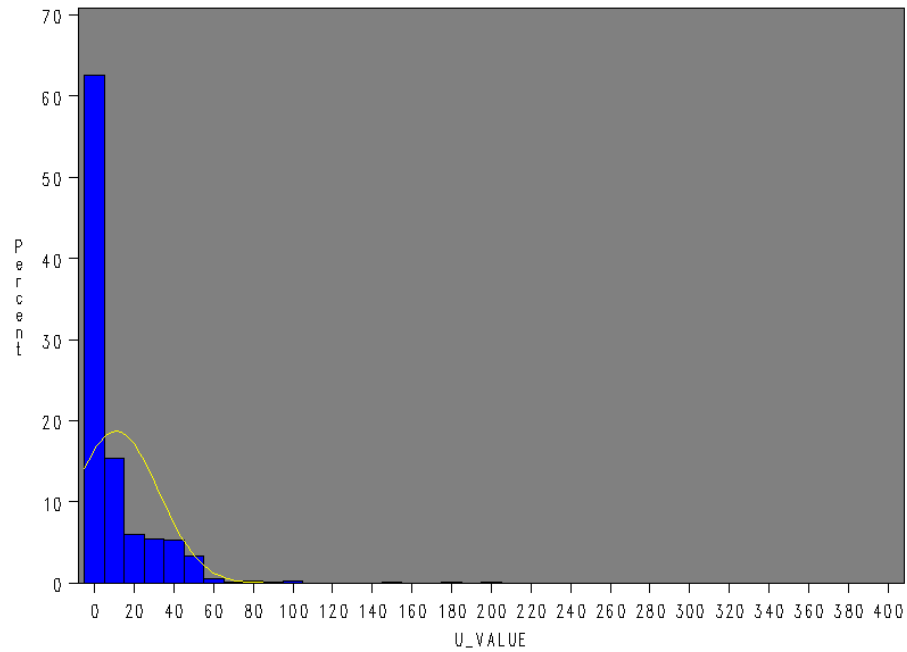FIGURES 4.22-4.24 show the histogram, normal quantiles, and box plot for the distribution of unit values ($/ft^2) of parcel elements in the population that meets rail station conditions of PTA criteria.
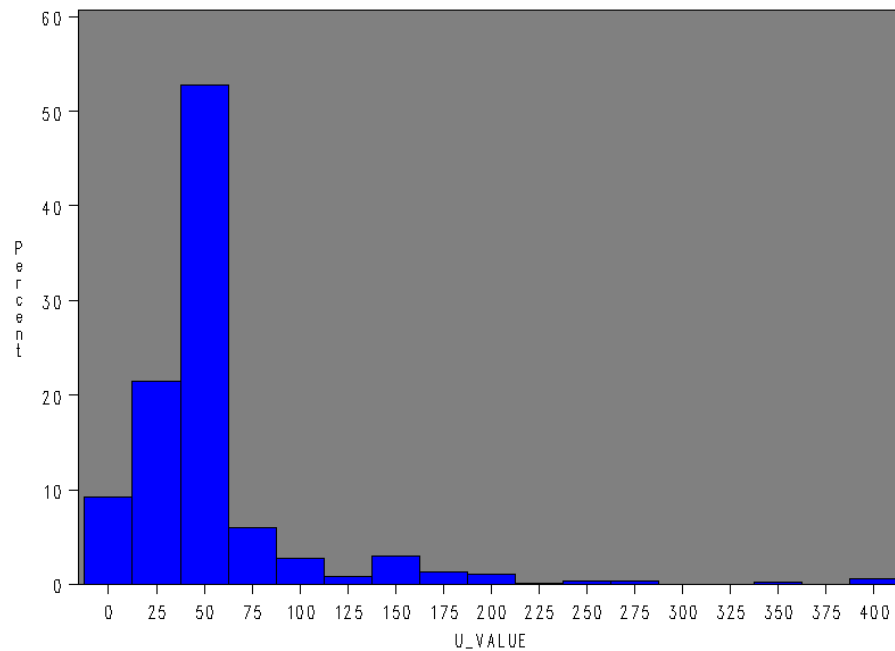
FIGURE 4.22 Histogram for the Railroad Station Conditions of the SSC #4.1
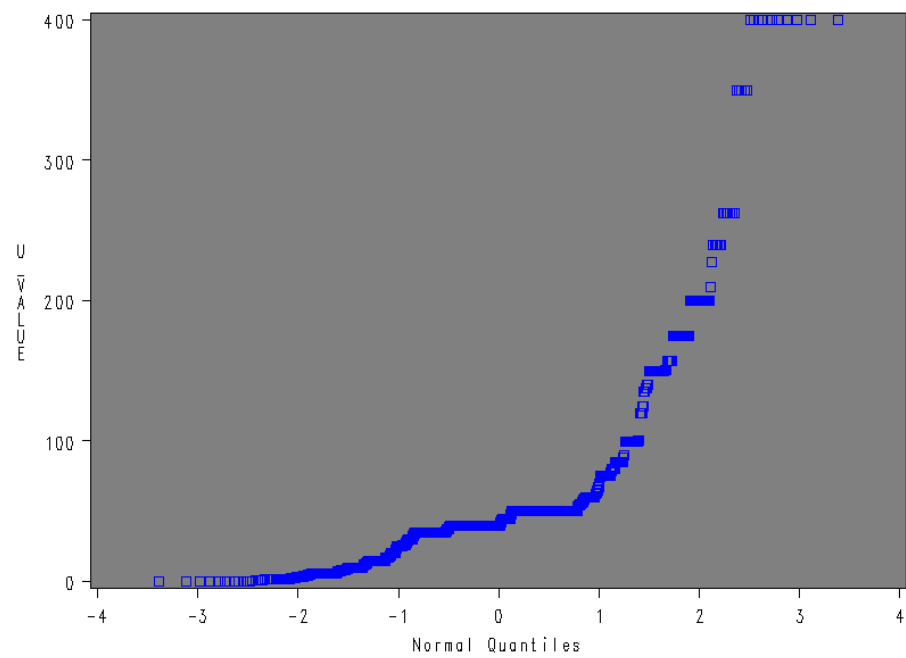
FIGURE 4.23 Normal Quantiles for the Railroad Station Conditions of the SSC #4.1
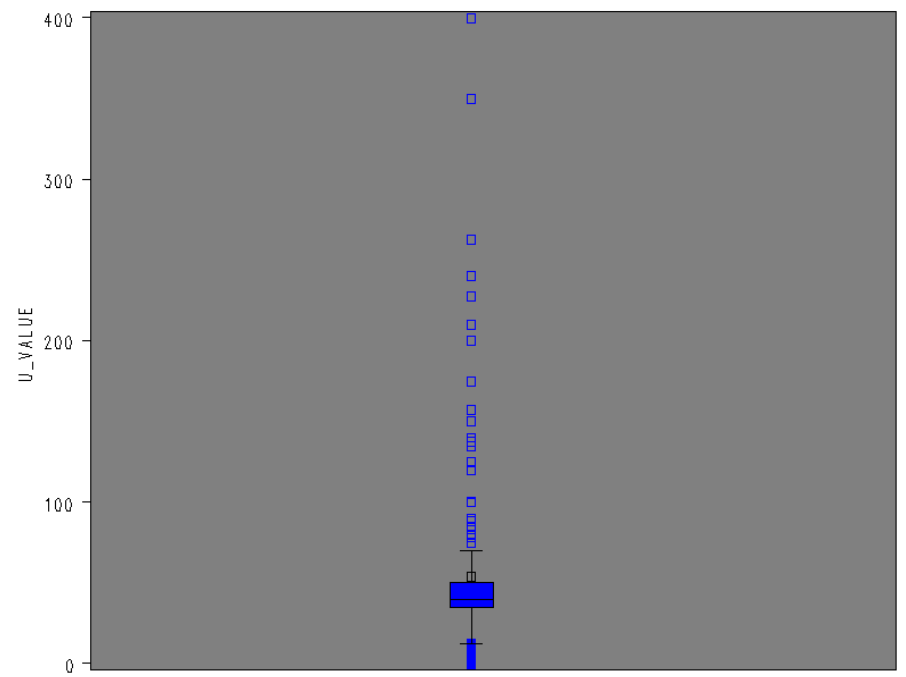
FIGURE 4.24 Boxplot for the Railroad Station Conditions of the SSC #4.1

4.1.1.3. Interpretation

Observing FIGURES 4.1-4.24, it is clear that the data distribution of all

populations is not normal but left-skewed. Furthermore, one cannot ignore the gaps

between means and medians of each population.

The extreme values of the data are 400 ($/ft^2). These parcels are located in

downtown Houston, especially those which satisfy the condition of both rail stations and

bus stops of the PTA criteria. This means that the PTA is associated with and may be a

significant predictor of the value of the parcel. This relationship will be investigated

further in later sections of this study with bi- and multi-variate analysis.

4.1.2. Tabular Displays

4.1.2.1. Analysis

Tabular displays of descriptive statistics can show more detailed information

regarding data distribution. This enables one to better understand and figure out how the

data are distributed. In particular, the skewness and kurtosis values can provide

information of the data distribution with more detailed values, so it is possible to

determine the data distribution numerically.

Furthermore, the p-value expresses the normality of the data, and the quantiles

(range) shows the location of specific values such as the mean and median exactly.

4.1.2.2. Results

Results for the tabular displays are in TABLES 4.1-4.3.

TABLE 4.1 Statistical Measurement and Moment

Basic Statistical Measurement & Moment		No SSC#1	SSC#3	SSC#4.1	Overall
Observations	N	16,140	273	16,306	24,803
	N/123,736(%)	13.0439	0.2206	13.1781	20.0451
	N/614,758(%)	2.6254	0.0444	2.6524	4.0346
Mean	Estimate	3.1992	12.5807	14.9450	10.9276
	95% Lower Confidence Limit	3.0565	10.5973	14.5642	10.6621
	95% Upper Confidence Limit	3.3419	14.5640	15.3258	11.1932
Std Deviation	Estimate	9.2474	16.6457	24.8090	21.3358
	95% Lower Confidence Limit	9.1476	15.3567	24.5426	21.1497
	95% Upper Confidence Limit	9.3494	18.1727	25.0812	21.5253
Std Error Mean		0.0728	1.0074	0.1943	0.1355
Skewness		13.2962	2.7877	6.1542	7.0083
Kurtosis		37.9352	12.6371	66.8532	88.0426
Modes	Mode	1.0000	4.0000	4.5000	2.0000
	Count	442	15	450	640

TABLE 4.2 Test for Normality for the Population

Estimates	SSC#1	SSC#3	SSC#4.1	Overall
Statistics	0.3647	0.6716	0.2735	0.3043
p Value	<0.0100	<0.0100	<0.0100	<0.0100

TABLE 4.3 Quantiles and Robust Measurement Scale for the Population

Estimates		SSC #1	SSC #3	SSC #4.1	Overall	Remarks
	100.0	400.0000	135.0000	400.0000	400.0000	Max
	99.00	40.0000	51.7500	100.0140	80.0000	
	95.00	15.0000	45.0001	50.0000	45.0000	
	90.00	5.5000	36.0000	40.0001	35.0000	
	75.00	2.4206	12.0002	22.0000	10.0002	Q3
Quantile (%)	50.00	0.9709	6.6000	5.0000	3.0000	Median
	25.00	0.4019	2.7922	2.0000	1.2720	Q1
	10.00	0.2250	1.5000	1.1000	0.5000	
	5.000	0.1148	0.9000	0.7500	0.3000	
	1.000	0.0500	0.3000	0.1157	0.0830	
	0.000	0.0000	0.0250	0.0030	0.0023	Min
Interquartile Range		2.0187	9.2080	20.0000	8.7282	
Range		400.0000	134.9750	399.9977	399.9977	

4.1.2.3. Interpretation

The only attribute information obtained by GIS analysis is the account number of each parcel associated with each criterion. All other attribute information is in spreadsheets. Thus, for obtaining required data such as acres, appraised value, use, and so on, the account number is used as the key to associate the selected parcel and its attribute information.

TABLE 4.1 shows the result of univariate analysis for each population. According to the obtained data, just 33 regions are defined as brownfields by the City of Houston, and there are just 231parcels in these regions. For all the unimproved parcels in Harris County, the percentages which belong to SSC #1, SSC #3, SSC #4.1, and the overall

model are around 2.6%, 0.04%, 2.7%, and 4%, respectively. Whereas the percentages of

the selected parcels for SSC #1, SSC #3, SSC #4.1, and the overall model versus the

number of parcels in Houston is around 13%, 0.02%, 13.2%, and 20%, respectively.

For reference, the number of parcels in Harris County and the City of Houston are

614,758 and 123,736, respectively. Due to some overlapping of parcels among

sustainable credit criteria, the total number of parcels in the overall model (24,803) does

not equal the sum of parcels for all criteria.

Lastly, the mean unit value of parcels for SSC #4.1 is highest among all population

groups, and the next highest is SSC #1. Thus, it is important to investigate these two

variables more carefully in the next steps of the study.

4.2.   Bi-Variate

The aim of this section is to identify the correlation between variables prior to

more complex multi-variate analysis.

First of all, it is unacceptable to use the raw data because the data is non-

normally distributed. Thus, it is necessary to transform the data normally. In this study,

natural log transformation was used for making data behave normally. The data

transformation process details will be discussed in the next multi-variate analysis section.

4.2.1.   Overall Model

4.2.1.1.   Analysis

There are 12 outliers with residuals bigger than 3.0000 in this dataset. Among

them, five parcels (account numbers 1180180010021, 1187810010020, 1190360010014,

0060030000030, and 0591290030012) as written in TABLE 4.4 are not valid as

elements of the sample. The use of these parcels is mainly for the agriculture and

parking. In addition, one of these parcels contains a five-story office building. According

to the information for this parcel, it is recorded as the unimproved land. This is probably

a mistaken entry. Nevertheless, for the fundamental statistical analysis, it is required to

delete these five parcels from the list of sample elements.

TABLE 4.4 Outliers for the Overall Model

Account	SSC 1	SSC 3	SSC 4	ACRES	VALUE	Residual	Use
1180180010021	1	1	1	0.1066	0.0250	-6.4226	Agricultural Land
1187810010020	1	0	1	0.0118	0.2010	-4.1997	Agricultural Land
0651280540228	1	0	1	0.2837	0.1990	-4.1956	resident vacant
0210690040028	0	0	0	1.8270	0.0880	-3.5460	commercial vacant
1190360010014	1	0	1	0.0047	0.4880	-3.3123	Agricultural Land
0450020010189	0	0	0	1.1480	0.1210	-3.2600	Chemical & Allied Prod.
0422280010045	1	0	1	0.3794	0.5230	-3.2239	Commercial vacant
0410150110140	0	0	0	0.6618	0.1500	-3.0655	Commercial Vacant
0011420000002	1	1	1	0.1963	400.0000	3.2627	Commercial Vacant
0060030000030	1	0	1	1.4856	400.0000	3.4714	Office Bldgs
0591290030012	0	0	0	0.1099	108.0000	3.4859	Parking Lots
0601620920008	0	0	0	0.2720	330.0160	4.6110	Residential Vacant

4.2.1.2. Plots and Correlations

In this section, plots showing the relationship between independent variables

(ACRE, SSC1, SS3, and SSC4) and the dependent variable (TRANS_VALUE) were

drawn for understanding the correlations between variables graphically as shown in

FIGURES 4.25-4.28.
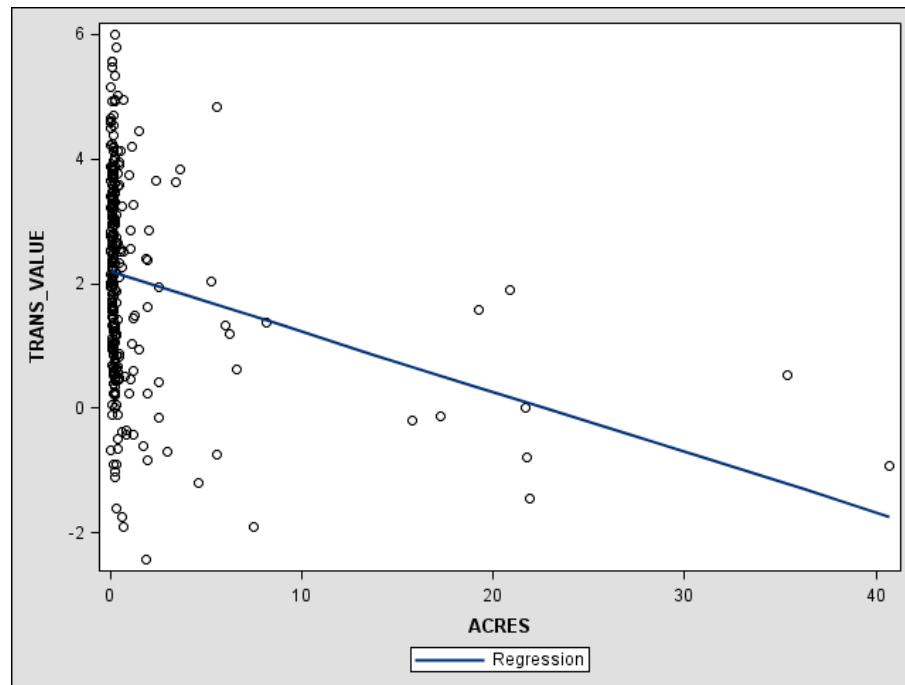
FIGURE 4.25 Correlation between Variables, TRANS_VALUE and ACRES
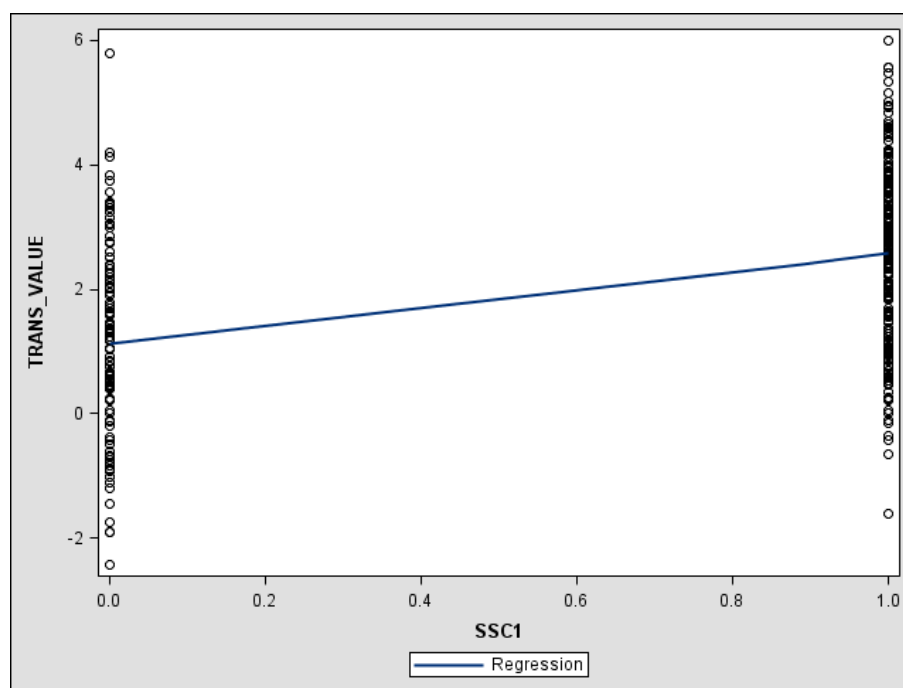
FIGURE 4.26 Correlation between Variables, TRANS_VALUE and SSC1

FIGURE 4.27 Correlation between Variables, TRANS_VALUE and SSC3

FIGURE 4.28 Correlation between Variables, TRANS_VALUE and SSC4

The correlations between the transformed response in this model,

TRANS_VALUE, and the independent variables, SSC1, SSC3, SSC4, and ACRE are

shown in TABLE 4.5.

TABLE 4.5 Correlations for the Overall Model

Variable	SSC1	SSC3	SSC4	ACRE	TRANS_VALUE
With Inapt Parcels	0.3836	0.0256	0.4047	-0.2416	1.000
Without Inapt Parcels	0.4186	0.0483	0.4426	-0.2623	1.000

4.2.2.   Public Transportation Access Model

4.2.2.1.   Analysis

Prior to the correlation analysis, it is indispensible to check the outliers as in the

model above. There were 14 observed data whose absolute value of the residual is greater than 3.0 as shown in TABLE 4.6. Among them, 3 sampled data were investigated as suspect parcels to use in this study. The account numbers of these parcels are 0102490000029, 1190360010012, and 0591290030012. For reference, the services of these parcels are the agricultural land or parking lot. Although there is no building or just auxiliary facilities in these parcels, these parcels are not unimproved.

Thus, in this study, these inappropriately sampled parcels were also eliminated and the correlations between variables are shown and calculated with graphs and detailed figures.

TABLE 4.6 Outliers for the PTA Model

Account	Bus	Rail	Acre	Value	Residual	Use
0102490000029	1	1	0.831	0.44	-4.45244	Agricultural Land
0210690040028	0	0	1.827	0.088	-3.53435	Commercial Vacant
0580900030009	1	0	0.046	0.22	-3.53398	Commercial Vacant
0681210070004	0	0	0.481	0.101	-3.41775	Commercial Vacant
0122420490001	0	0	3.7	0.1	-3.35287	Commercial Vacant
0462120000017	1	0	0.11	0.3	-3.22204	Commercial Vacant
0642250110034	0	0	5.605	0.116	-3.16511	Residual Vacant
1062260000002	0	0	9.65	0.105	-3.16444	Commercial Vacant
0661090040009	1	0	0.48	0.344	-3.07653	Residual Vacant
1190360010012	1	0	0.007	0.352	-3.06568	Agricultural Land
0540890000018	0	0	0.164	83.204	3.28401	Residual Vacant
0591300090008	0	0	0.138	90	3.36191	Residual Vacant
0591290030012	0	0	0.11	108	3.54358	Parking Lots
0770070020007	1	0	0.024	371.333	3.89674	Commercial Vacant

4.2.2.2.   Plots and Correlations

TABLE 4.7 shows the correlation between the response and each independent variable before and after eliminating inappropriately selected parcels, respectively.

TABLE 4.7 Correlations for the PTA Model

Variable	BUS	RAIL	ACRE	TRANS_VALUE
With Inapt Parcels	0.3173	0.4584	-0.2420	1.000
Without Inapt Parcels	0.3431	0.4765	-0.2471	1.000

Additionally, FIGURES 4.29-4.31 show the correlation between variables graphically.

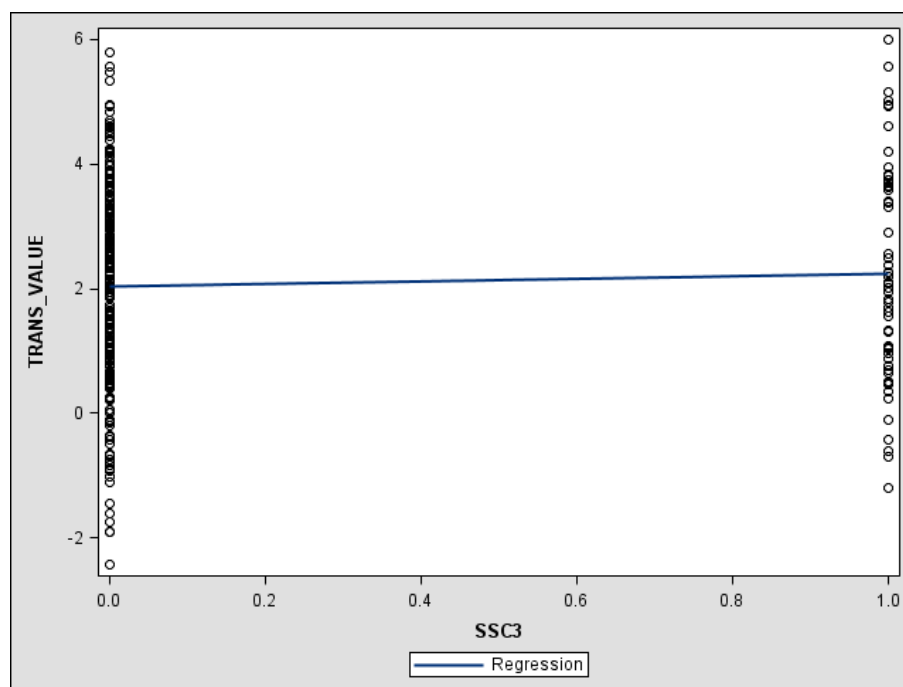FIGURE 4.29 Correlation between Variables, TRANS_VALUE and ACRE
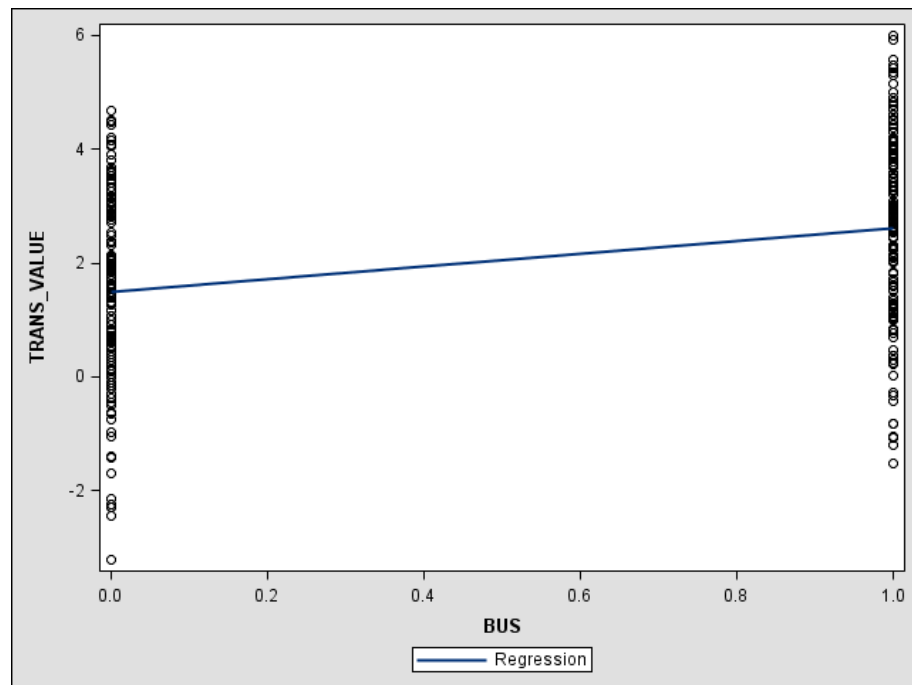
FIGURE 4.30 Correlation between Variables, TRANS_VALUE and BUS
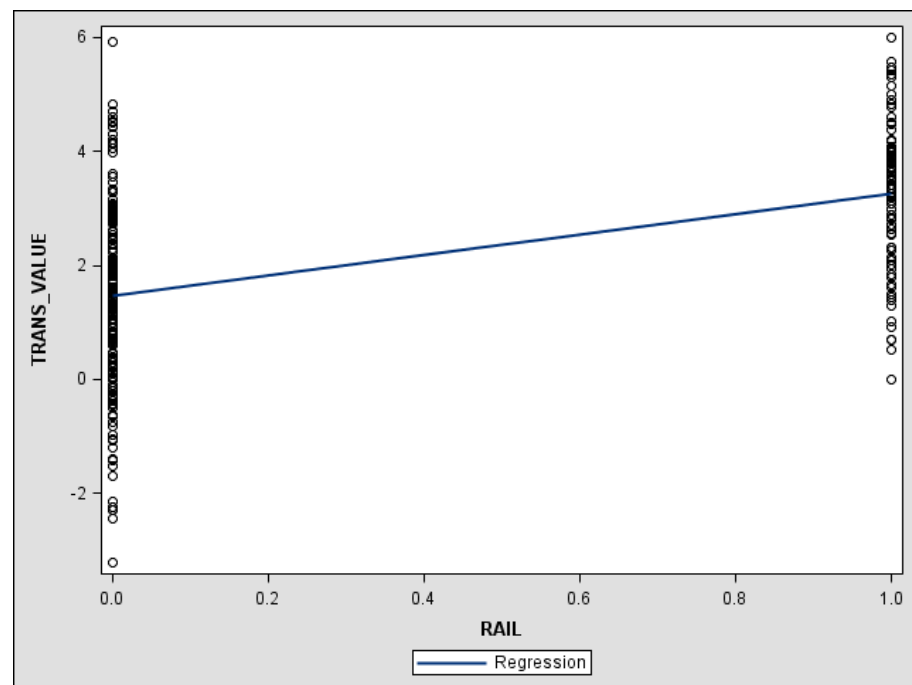
FIGURE 4.31 Correlation between Variables, TRANS_VALUE and RAIL

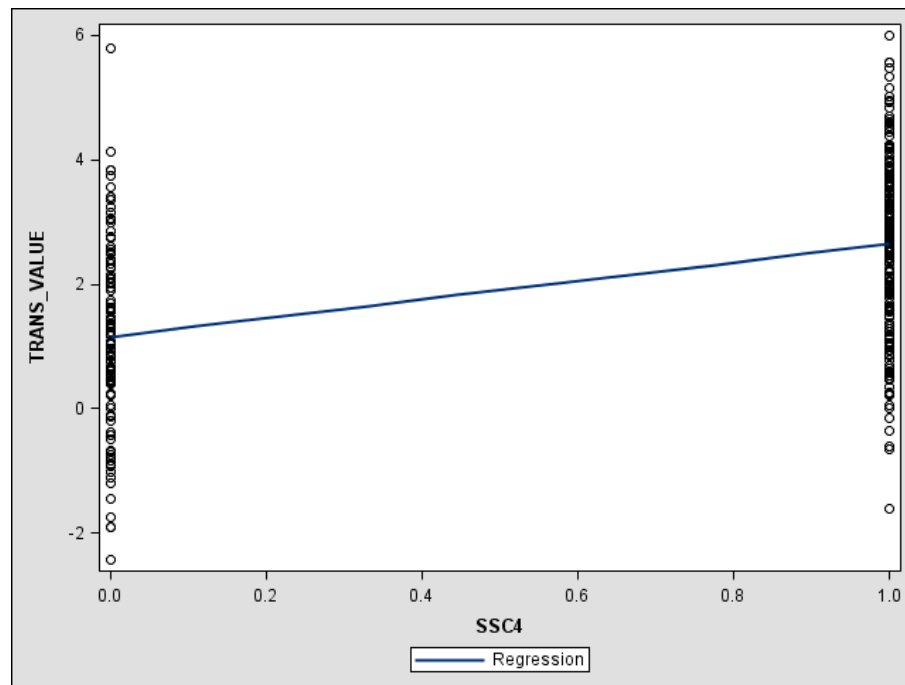4.2.3.   Correlations between Independent Variables

4.2.3.1. Analysis

Although the interaction effects between independent variables were not used in the proposed model, it is also important to identify them. To investigate the correlations between independent variables, regression trend lines and correlation values are also used.

4.2.3.2. Plots and Correlations

FIGURES 4.32-4.40 show the regression trend lines to reflect how much two independent variables are correlated each other.
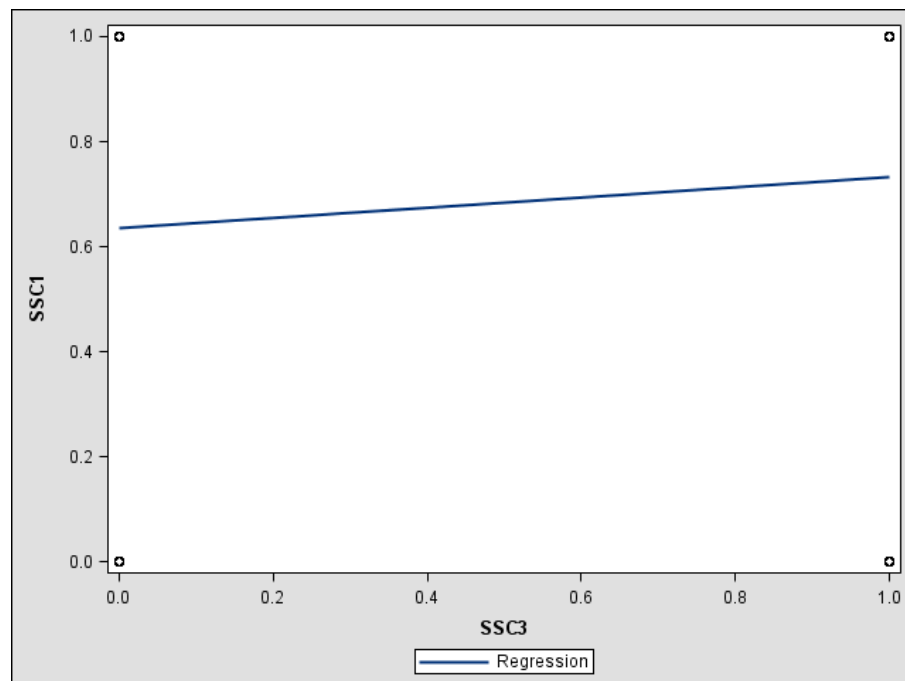
FIGURE 4.32 Correlation between Variables, SSC1 and SSC3
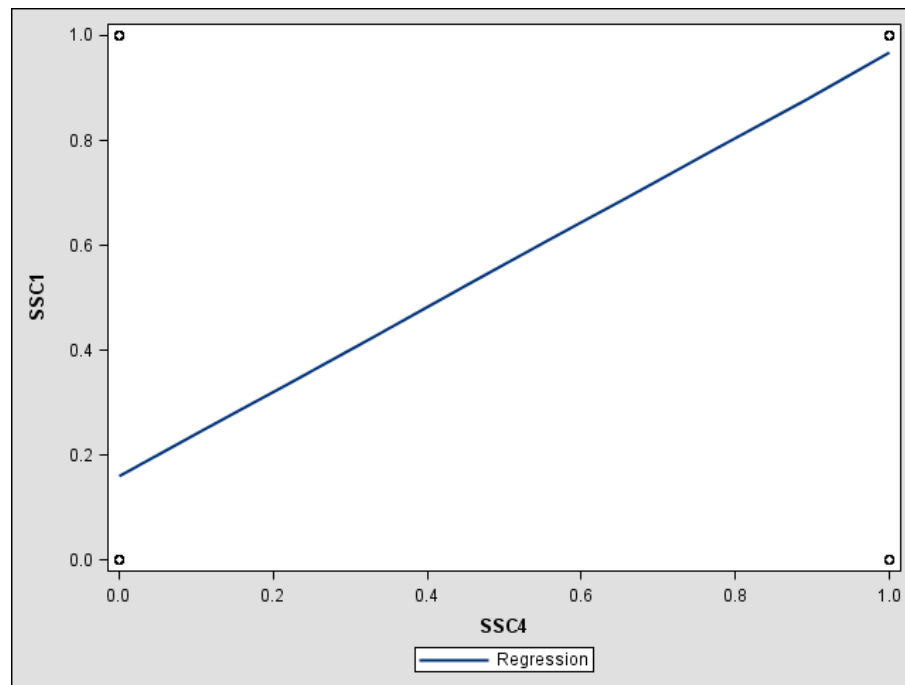
FIGURE 4.33 Correlation between Variables, SSC1 and SSC4
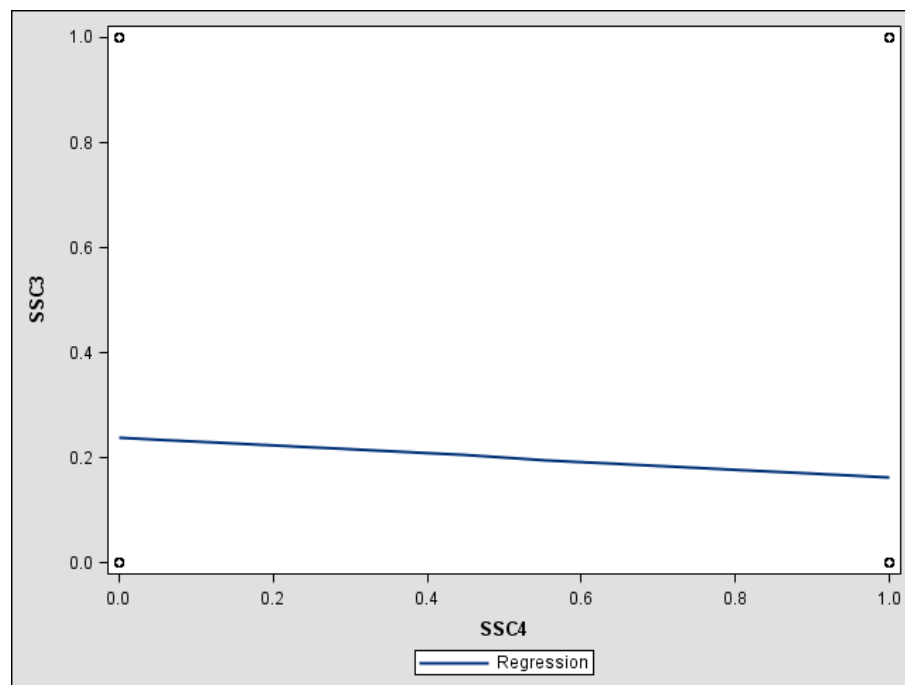
FIGURE 4.34 Correlation between Variables, SSC3 and SSC4
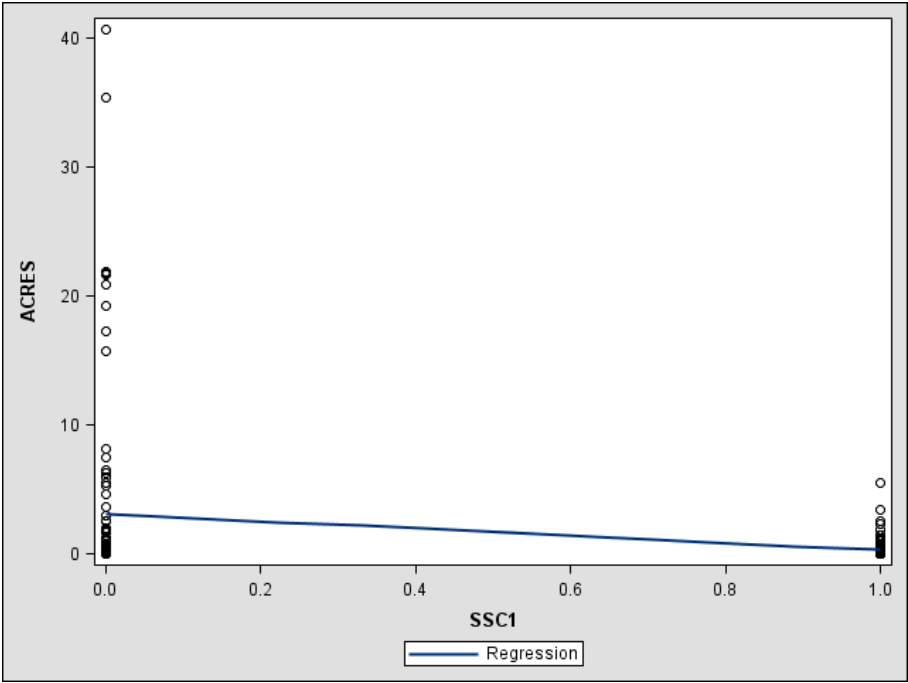
FIGURE 4.35 Correlation between Variables, ACRE and SSC1
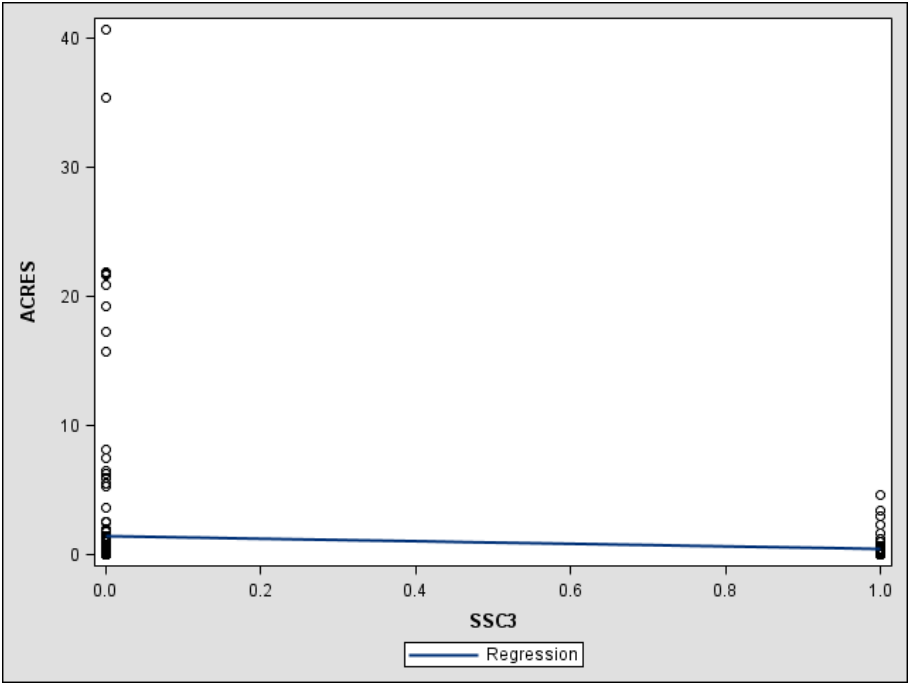
FIGURE 4.36 Correlation between Variables, ACRE and SSC3
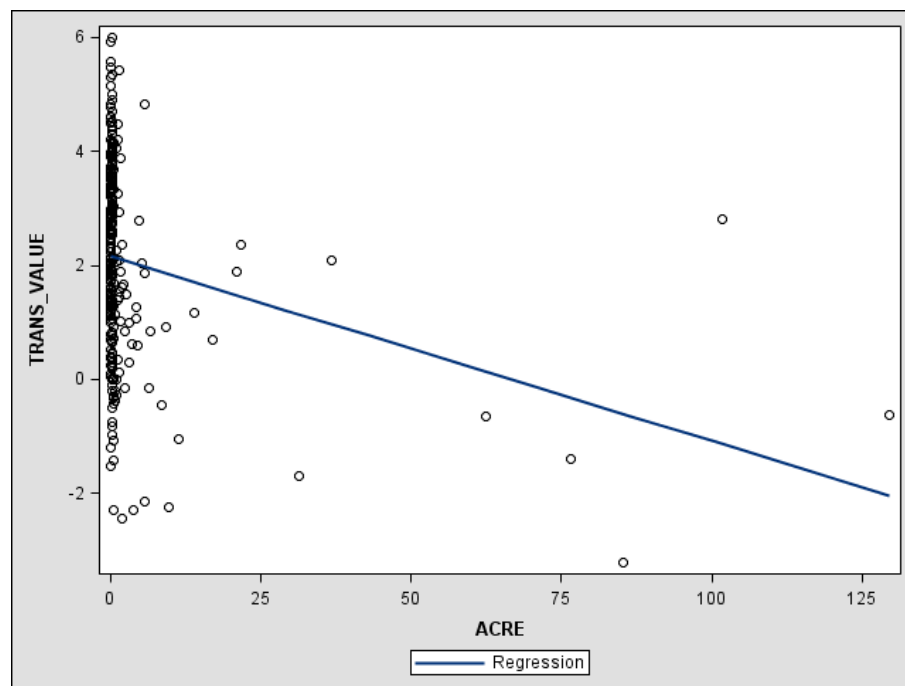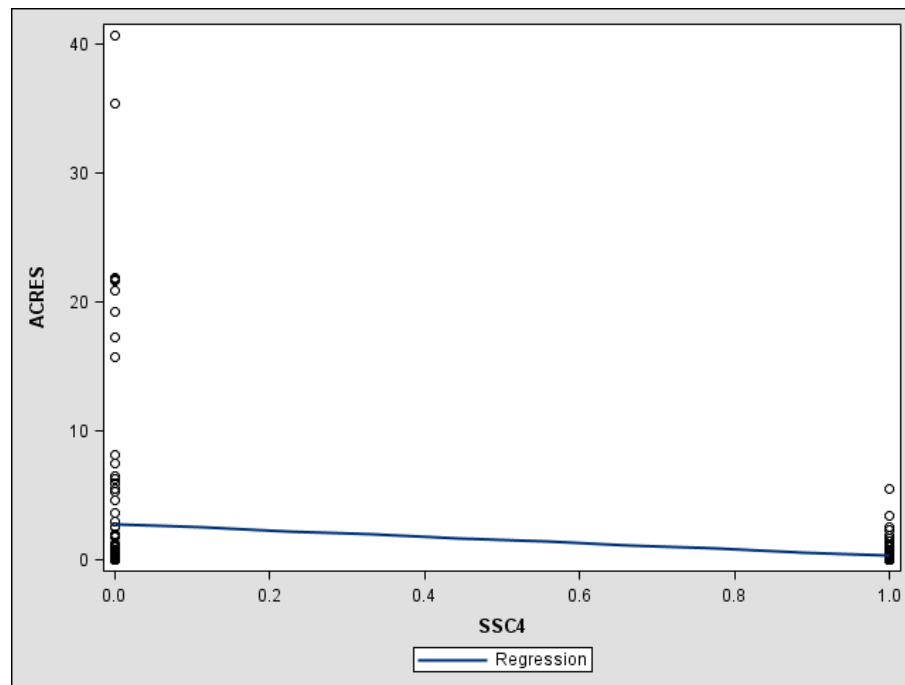
FIGURE 4.37 Correlation between Variables, ACRE and SSC4
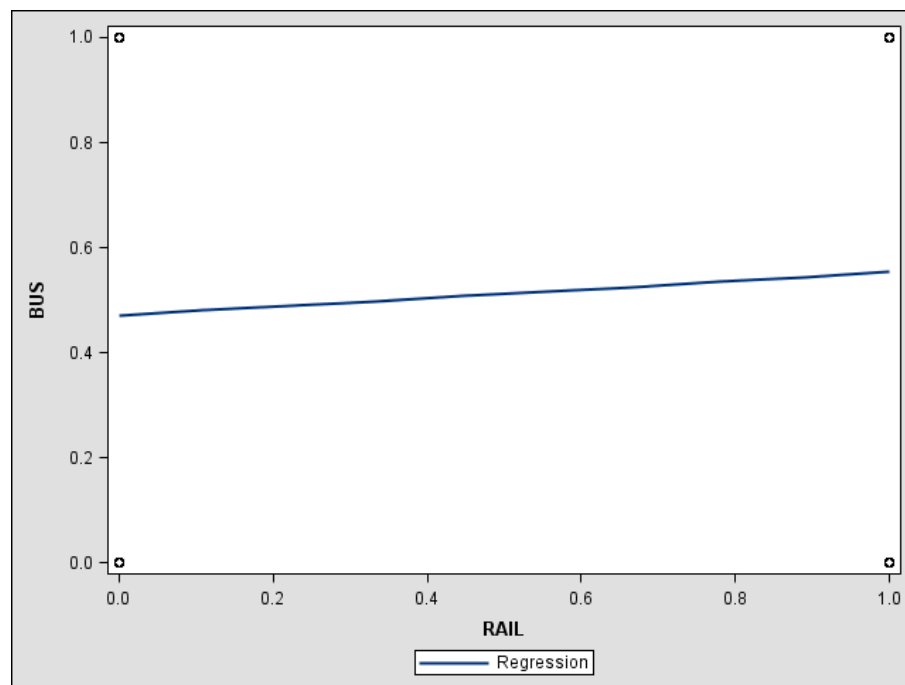
FIGURE 4.38 Correlation between Variables, BUS and RAIL
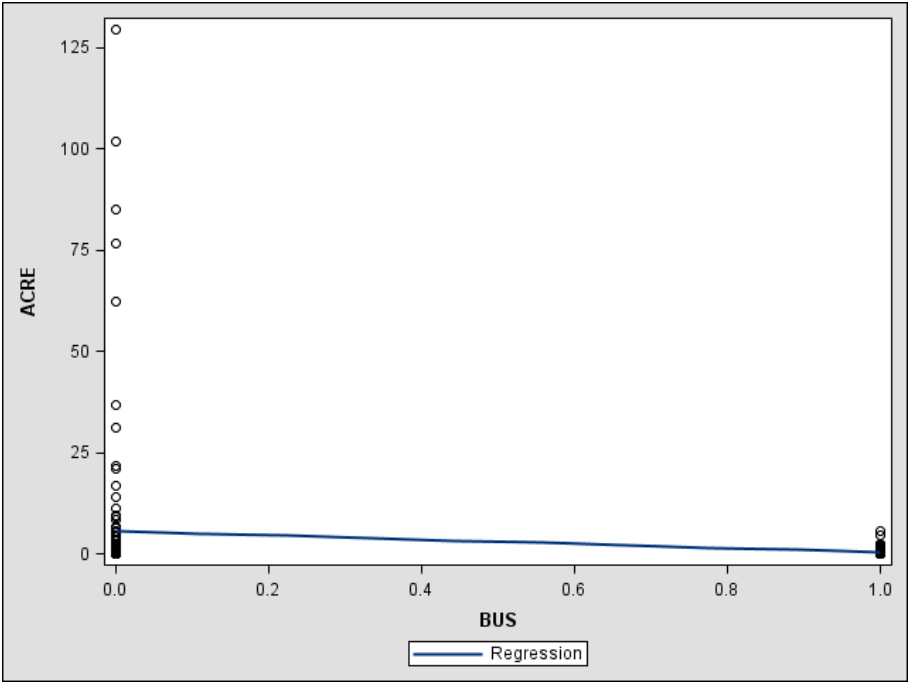
FIGURE 4.39 Correlation between Variables, ACRE and BUS
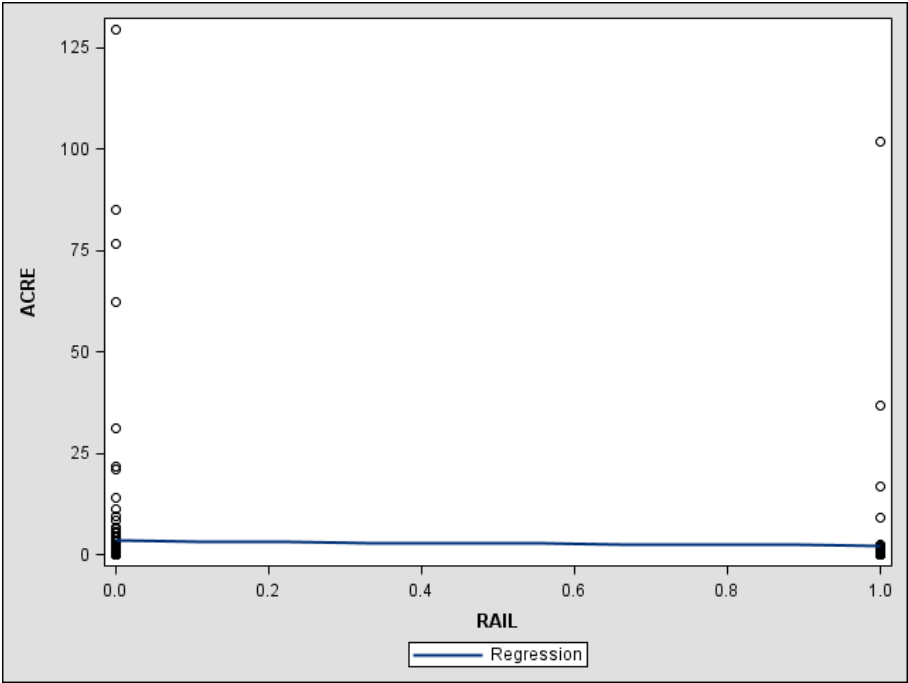
FIGURE 4.40 Correlation between Variables, ACRE and RAIL

Additionally, the correlations between independent variables are summarized as written in TABLES 4.8-4.9. TABLE 4.8 is a correlation matrix between independent variables, ACRE, SSC1, SSC3, and SSC4 used in the overall model, and TABLE 4.9 is a correlation matrix between independent variables, ACRE, BUS, and RAIL used in the individual PTA Model.

TABLE 4.8 Correlation between Independent Variables of the Overall Model

Variable	ACRES	SSC1	SSC3	SSC4
ACRE	1	-0.3017	-0.0864	-0.2731
SSC1	-0.3017	1	0.0799	0.8265
SSC3	-0.0864	0.0799	1	-0.0952
SSC4	-0.2731	0.8265	-0.0952	1

TABLE 4.9 Correlation between Independent Variable of the PTA Model

Variable	BUS	RAIL	ACRE
BUS	1	0.0772	-0.198
RAIL	0.0772	1	-0.0403
ACRE	-0.198	-0.0403	1

4.2.4.   Interpretation

4.2.4.1. Overall Model

The value of the correlations after deleting the inappropriate parcels is somewhat higher than the previous ones as shown in TABLE 4.5.

Additionally, according to TABLE 4.5 and FIGURES 4.25-4.28, all independent

variables, SSC1, SSC3, and SSC4 have positive relations with the dependent variable, TRANS_VALUE, without the variable, ACRE. Specifically, the variables, SSC1 and SSC4, are highly correlated with the dependent variable, TRANS_VALUE. Otherwise, SSC3 has the weakest correlation with the dependent variable.

4.2.4.2. Public Transportation Access Model

As shown in TABLE 4.7, the correlations between BUS and TRANS_VALUE and between RAIL and TRANS_VALUE are positive, but the one between ACRE and TRANS_VALUE is negative. This means that the existing bus stops or rail stations are positively related with the unit value of parcels as shown in FIGURE 4.30 and FIGURE 4.31. On the other hand, as the size of parcels decreases, the unit value of the parcels increases as shown in FIGURE 4.29.

4.2.4.3. Correlation between Independent Variables

Although the interaction effects between independent variables were not used in the proposed models, thinking about the correlations between BUS and ACRE, ACRE and SSC1, ACRE and SSC4, and SS1 and SSC4 cannot be ignored. The noticeable result is that the variable ACRE is correlated with all variables considered in both predicting models. In particular, the correlation between SSC1 and SSC4 is the highest among all of the possible combinations. For the advanced study, it is better to consider these correlations in the model.

Lastly, the values of the correlation without suspect parcels are also generally

slightly higher than the ones with suspect parcels.

4.3. Multi-Variate

4.3.1. Analysis

The main purposes of this section are to develop linear regression models for predicting the unit value of unimproved, private parcels and to determine the magnitude and significance each independent variable contributes to the unit value of the parcels. Furthermore, with ANOVA, the effect of the criteria to constitute the unit value will be evaluated.

4.3.2. Regression

4.3.2.1. Overall Model

The basic moments for the descriptive statistics are as follows in TABLE 4.10. The ones deserving to be most closely inspected are cases where both skewness and kurtosis have few values which are not close to zero. The plus skewness of 4.3066 indicates that the distribution of the sampled data for this model is considerably left-skewed as shown in FIGURE 4.41. This tendency is obvious when thinking about the locations of the mean and median in TABLE 4.10. The boxplot as shown in FIGURE 4.42 shows that the mean is located near the limit of the third-quantile range rather than near the median. In addition, the positive kurtosis value, 22.4911, displays a sharper peak for this distribution than the one with normal distribution as shown in FIGURE 4.43.

Furthermore, the p-value for the normality test is lower than 0.0100 as shown in TABLE 4.12. For reference, the null hypothesis regarding the test for normality is that the distribution of the residuals is normal. Thus, this p-value rejects the null hypothesis; namely, the distribution of the residuals is not normal. This assessment can be checked through FIGURE 4.44 which shows the Q-Q plots for the non-normal distribution of the residuals.

Thus, it is easy to determine transformation of the data is required to form a normal distribution; one of the most important and first jobs prior to performing the principle statistical analysis. In this study, natural log transformation was used for making data behave normally as shown in Equation 4.1. TABLE 4.11 shows the why the data need to be transformed with the skewed values such as its median, interquatile ranges, and range.

$$TRANS\_VALUE = LOG(VALUE) \hspace{3cm} Equation\ 4.1$$

TABLE 4.10 The Basic Measurement Scale of the Overall Model

Contents	Values	Contents	Values
N	292	Sum Weight	292
Mean	26.7880	Sum Observation	7822.0744
Std Deviation	53.2295	Variation	2833.3832
Skewness	4.3066	Kurtosis	22.4911
Uncorrected SS	1034051.7	Corrected SS	824514.5
Coeff Variation	198.7072	Std Error Mean	3.1150

TABLE 4.11 Quantiles and Robust Measurement Scale for the Overall Model

Estimates		Values ($/ft^2)	Remarks
	100.0	400.0000	Max
	99.00	330.0162	
	95.00	111.0416	
	90.00	62.9127	
	75.00	26.3879	Q3
Quantile (%)	50.00	8.2917	Median
	25.00	2.3084	Q1
	10.00	0.8625	
	5.000	0.4035	
	1.000	0.1205	
	0.000	0.0250	Min
Interquartile Range		24.0800	
Range		399.9750	

TABLE 4.12 Test for Normality for the Overall Model

Estimates	Values
Statistics	0.3076
p value	<0.0100
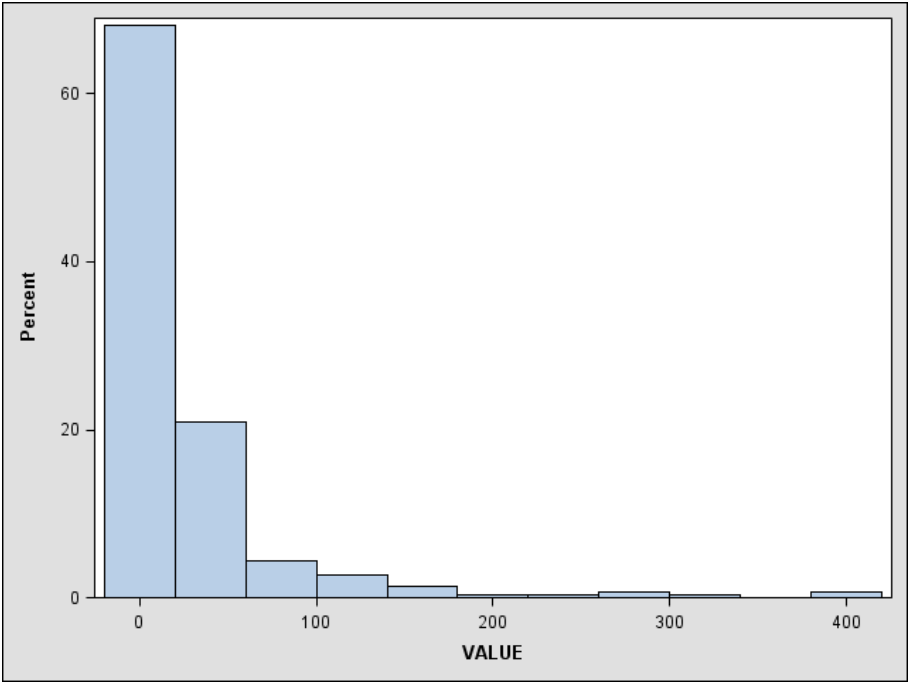
FIGURE 4.41 Histogram for the Overall Model
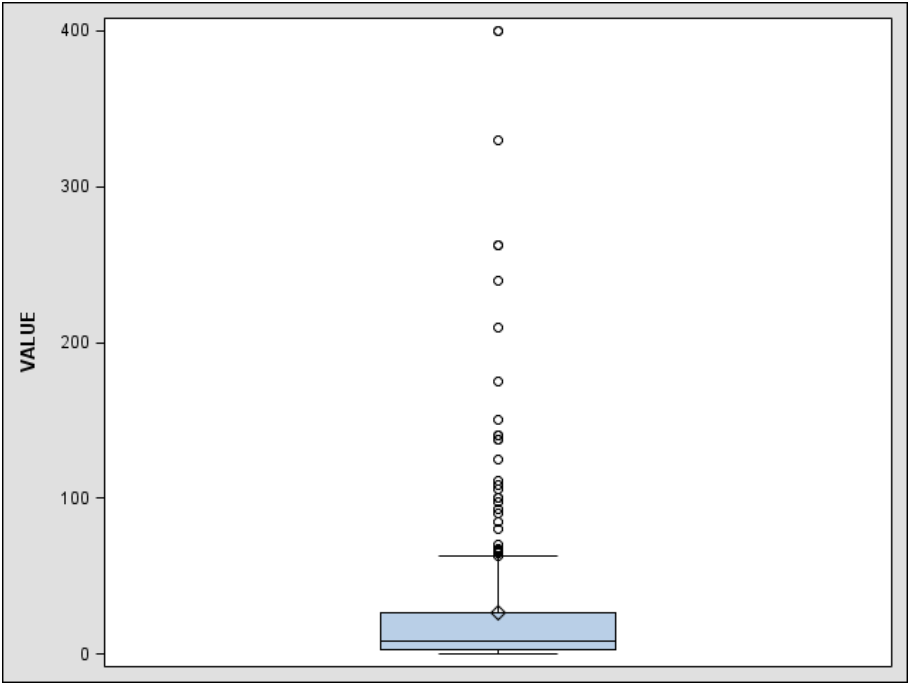
FIGURE 4.42 Boxplot for the Overall Model
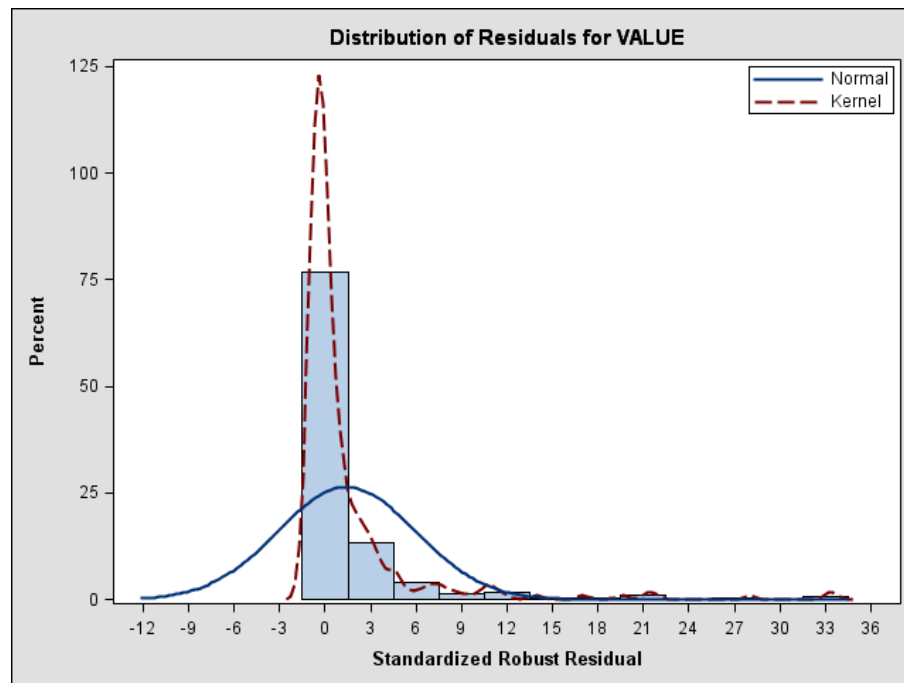
FIGURE 4.43 Residuals Distribution for the Overall Model
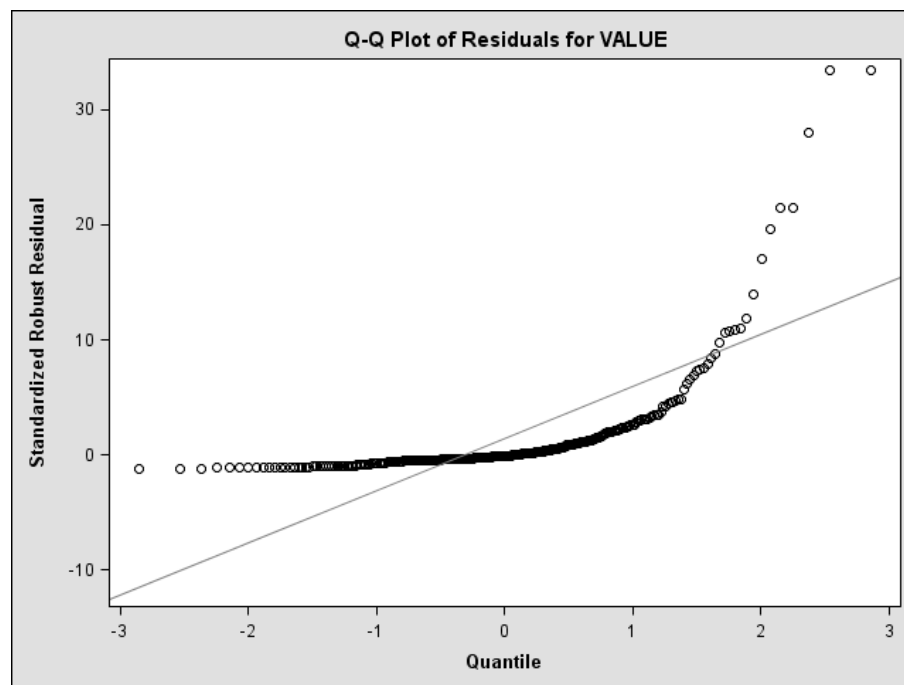
FIGURE 4.44 Residuals Plot for the Overall Model

TABLE 4.13 shows the analysis of variance for the suggested model in this section. The mean square error is 2.1265 and the p-value is almost zero. This p-value expresses the fact that at least one parameter estimate is not zero with rejecting the null hypothesis: all unknown parameter estimates are zero. In TABLE 4.14, the adjusted R-square is 0.2154. Although it is impossible to determine the outcome of this model with this adjusted R-square, it is possible to expect a better linear regression model to obtain better fit. For reference, although the R-square is lower than one might wish, it does not mean that this model is invalid.

TABLE 4.13 Analysis of Variance for the Overall Model

	DF	Sum of Sqr	Mean Sqr	F Value	p value
Model	4	174.9385	43.7346	20.57	<.0001
Error	281	597.5540	2.1265		
Corrected Total	285	772.4926			

TABLE 4.14 Model Summary for the Overall Model

Root MSE	**1.4583**	**R-Square**	**0.2265**
Dependent Mean	2.0694	Adj R-Sq	0.2154
Coeff Var	70.4671		

Additionally, with estimated parameters as shown in TABLE 4.15, the proposed model can be expressed as follows in Equation 4.2(a).

TRANS_VALUE =

1.175–0.050×ACRE+0.362×SSC1+0.259×SSC3+1.098×SSC4

Equation 4.2(a)

On the other hand, this equation is not appropriate to predict actual values of the parcel directly. Namely, the equation needs to be re-transformed to assess inversed values like Equation 4.2(b).

VALUE
$$=\text{EXP}(1.175-0.050\times\text{ACRE}+0.362\times\text{SSC1}+0.259\times\text{SSC3}+1.098\times\text{SSC4})$$
Equation 4.2(b)

TABLE 4.15 Parameter Estimates for the Overall Model

Effect	DF	Estim	Std Err	T value	P value	VIF
Int	1	1.1753	0.16783	7	<.0001	0
SSC1	1	0.3620	0.33499	1.08	0.2807	3.41594
SSC3	1	0.2590	0.23017	1.13	0.2614	1.10676
SSC4	1	1.0977	0.32646	3.36	0.0009	3.40396
ACRE	1	-0.0499	0.0204	-2.45	0.015	1.11225

P-values for variables, SSC1 and SSC3, in TABLE 4.15 are 0.2807 and 0.2614, respectively. These values are much higher than the significant alpha value, 0.05, so that it is concluded that the variables, SSC1 and SSC3, are not significant in the established model to predict values of the parcel. This means that LEED categorical conditions for the site selection and brownfield are not good predictors of parcel unit value in Houston. On the other hand, the LEED condition regarding PTA is strongly significant.

Furthermore, all values of VIF are lower than 10 as shown in the last column of TABLE 4.15. This means that multi-collinearity is not a problem between the independent variables.

The graphs in FIGURE 4.45 show that the residual for the transformed data is normally distributed. Thus, this statistical analysis can be accepted reasonably, although there are some points which need to be checked in Cook's D chart. However, there is no problem regarding these data.
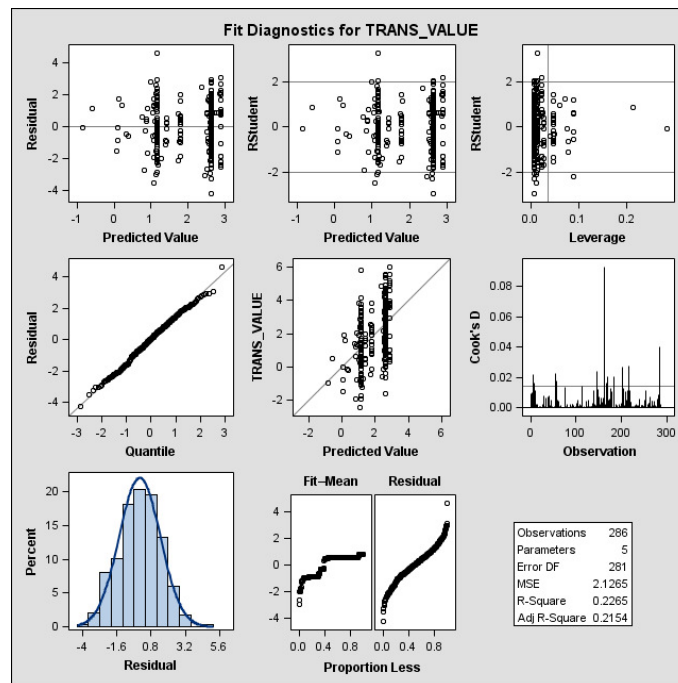
FIGURE 4.45 Transformed Data Fit Diagnostics for the Overall Model

Models calculated by PROC MIXED, PROC GLIMMIX, and PROC REG are approximately equal as shown in TABLE 4.16.

According to PROC MIXED and PROC GLIMMIX analysis as shown in TABLE 4.17, the p-values for variables, SSC1 and SSC3, are still higher than the significant value, 0.05. The only significant variable is SSC4. Moreover, the difference in least square means for the variable, SSC4, is meaningfully significant.

TABLE 4.16 Comparison of Prediction for the Overall Model

Categorical Values			Prediction Model	
SSC1	SSC3	SSC3	PROC REG	PROC GLIMMIX and MIXED
0	0	0	1.1753-0.0499×ACRE	1.1753-0.0499×ACRE
1	0	0	1.5373-0.0499×ACRE	1.5373-0.0499×ACRE
1	0	1	2.6350-0.0499×ACRE	2.6350-0.0499×ACRE
1	1	0	1.7963-0.0499×ACRE	1.7963-0.0499×ACRE
1	1	1	2.8940-0.0499×ACRE	2.8940-0.0499×ACRE
0	0	1	2.2730-0.0499×ACRE	2.2730-0.0499×ACRE
0	1	0	1.4343-0.0499×ACRE	1.4343-0.0499×ACRE
0	1	1	2.5320-0.0499×ACRE	2.5320-0.0499×ACRE

TABLE 4.17 Test of Fixed Effects of the Overall Model

Effect	Num DF	Den DF	F Value	p value
ACRE	1	281	5.99	0.015
SSC1	1	281	1.17	0.2807
SSC3	1	281	1.27	0.2614
SSC4	1	281	11.31	0.0009

Finally, considering the residual distribution and Q-Q plots by PROC GLIMMIX analysis as shown in FIGURE 4.46, the studentized residuals for VALUE is also normally distributed.
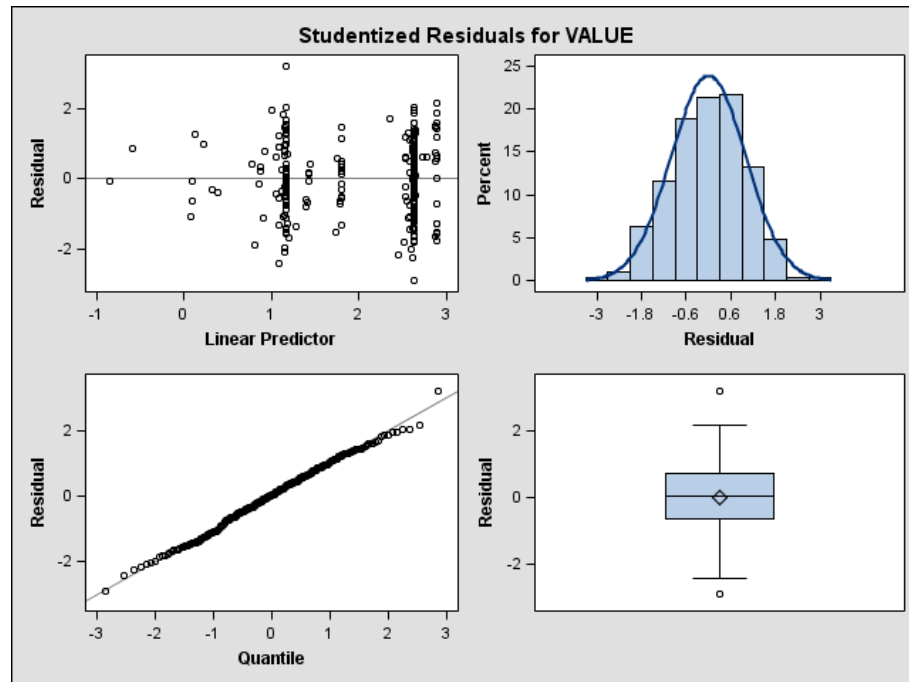
FIGURE 4.46 Residual by Proc Mixed for the Overall Model

4.3.2.2. Public Transportation Access Model

TABLE 4.18 shows the basic moments as outcomes for the descriptive statistics. It is noticeable that the values of both skewness and kurtosis are also far from zero like the overall model.

The positive skewness, 3.9904, means that the sampled data are also left-skewed. This can be checked graphically with the histogram as shown in FIGURE 4.47. The boxplot in FIGURE 4.48 shows that the mean, 27.7920, in TABLE 4.18 is nothing like

the median, 7.9412, in TABLE 4.19. This mean value is close to the third-quantile value, 23.6989.

Furthermore, the positive kurtosis value, 20.2227, reflects the fact that the data distribution peak is sharper than a normal distribution. It is possible to verify this fact through the distribution of the standardized robust residuals as shown in FIGURE 4.49. FIGURES 4.49 and 4.50 shows distribution and Q-Q plot of the residual for the PTA model respectively. These two values, skewness and kurtosis, indicate that the sampled data are not normally-distributed. TABLE 4.20 expresses the result of the test for normality. According to this p-value, <0.0100 means that it is appropriate to reject the null hypothesis: the distribution of the residual is normally-distributed. Namely, the distribution of the sampled data is not normal. FIGURE 4.19 expresses the Q-Q plot for the standardized robust residual. The distribution in this Q-Q plot is not aligned to the line. This exhibits the non-normal distribution of the sampled data visually.

Thus, it is required to transform data normally. In this study, considering that the distribution of the salaries and house prices are lognormal, log-transformation was performed to change the irregular distribution of the data to a normal one.

TABLE 4.18 The Basic Moment of the Descriptive Statistics for the PTA Model

Contents	Values	Contents	Values
N	260	Sum Weight	260
Mean	27.7920	Sum Observation	7225.9180
Std Deviation	52.0394	Variation	2708.1010
Skewness	3.9944	Kurtosis	20.2227
Uncorrected SS	902220.8	Corrected SS	701398.1
Coeff Variation	187.2461	Std Error Mean	3.2273

TABLE 4.19 Quantiles and Robust Measurement Scale for the PTA Model

Estimates		Values ($/ft^2)	Remarks
	100.0	400.0000	Max
	99.00	262.5002	
	95.00	115.5328	
	90.00	71.3300	
	75.00	28.6989	Q3
Quantile(%)	50.00	7.9412	Median
	25.00	2.3434	Q1
	10.00	0.7549	
	5.000	0.3524	
	1.000	0.1004	
	0.000	0.0400	Min
Interquartile Range		26.3555	
Range		399.9600	

TABLE 4.20 Test for Normality for the PTA Model

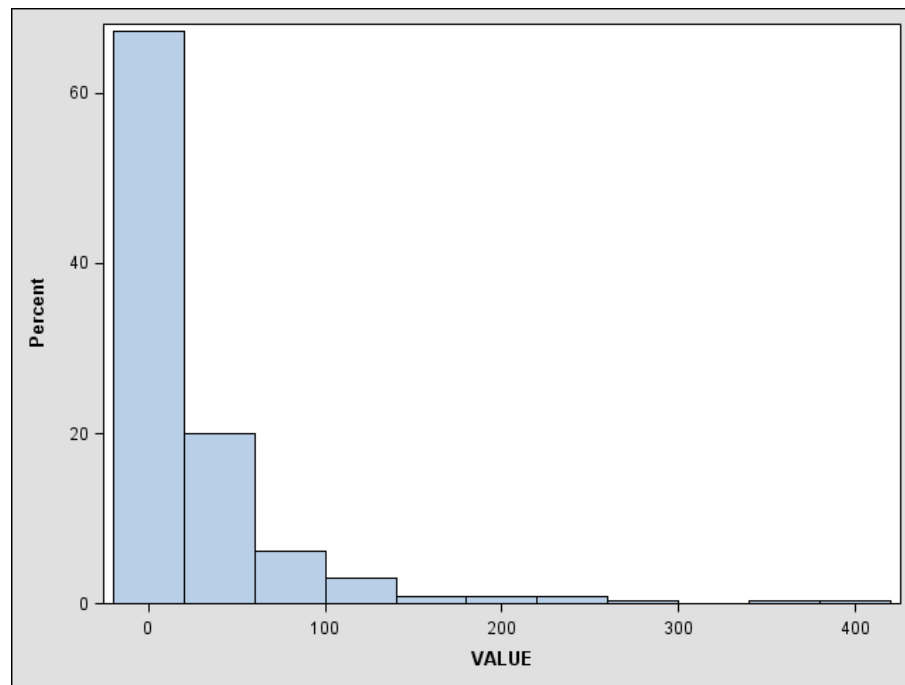| Estimates	Values
Statistics	0.2970
p Value	<0.0100

FIGURE 4.47 Histogram for the PTA Model
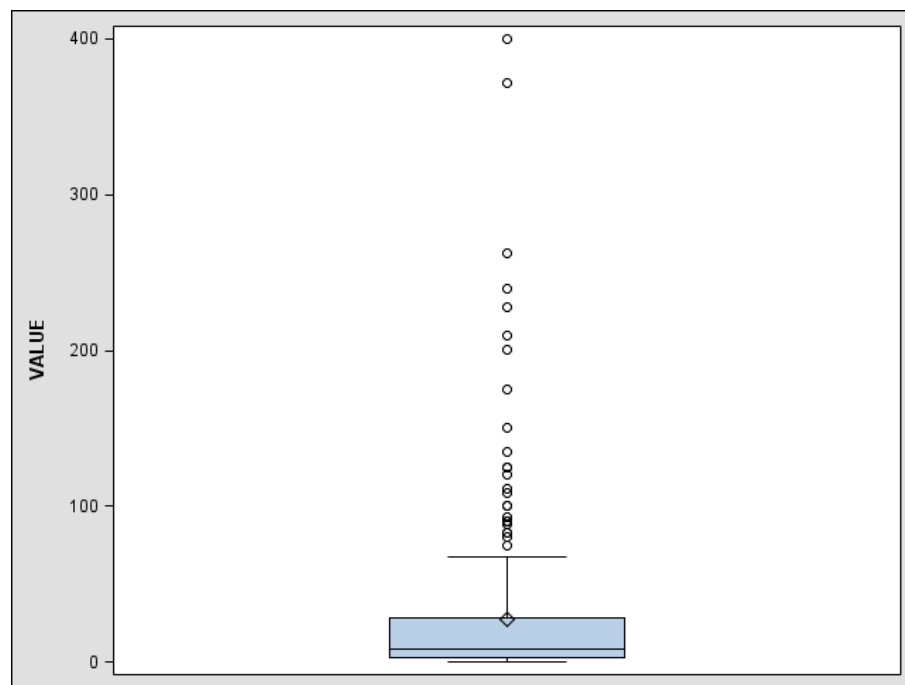
FIGURE 4.48 Boxplot for the PTA Model
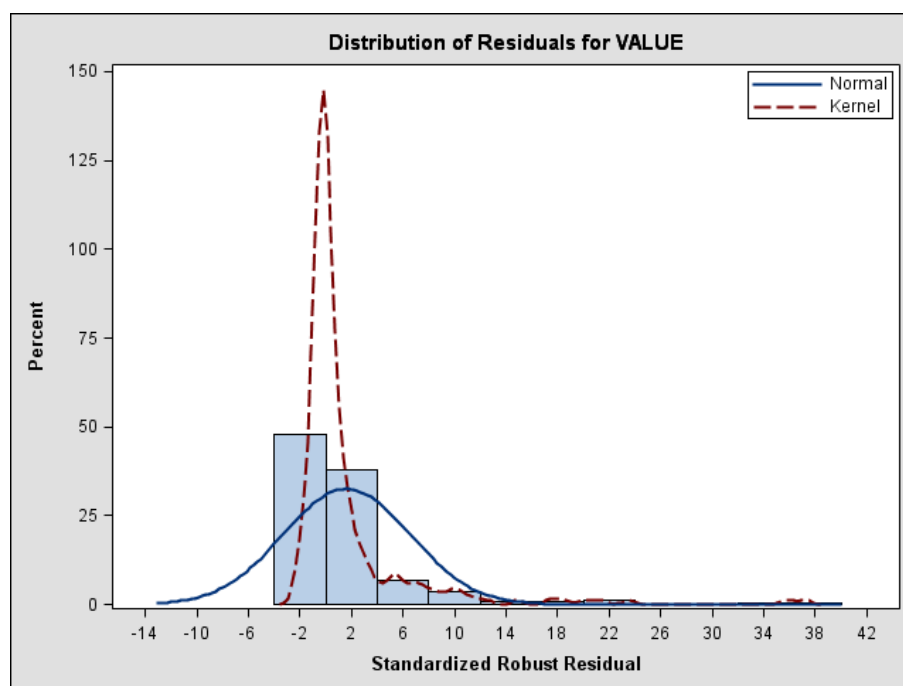
FIGURE 4.49 Residuals Distribution for the PTA Model
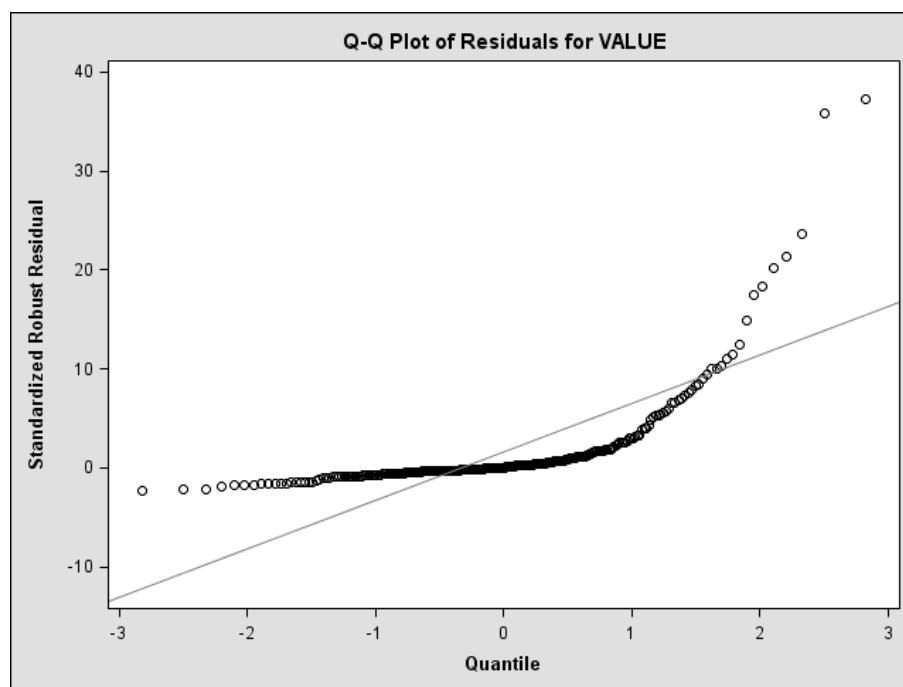
FIGURE 4.50 Residuals Plot for the PTA Model

TABLE 4.21 shows the analysis of the variance for the proposed model in this

section. In this model, the mean square error is 2.1892 and the p-value is <.0001. This p-

value means that the null hypothesis (all unknown parameter estimates are zero) is

rejected.   In TABLE 4.21, the adjusted R-square for this model is around 0.3431. This

means that around 65% to predict unit parcel values could be contributed by the other

factors or the interaction between the suggested factors. Although the adjusted R-square

is lower than hoped, this value seems reasonable. With estimated parameters in TABLE

4.22, the suggested model can be completed as following in Equation 4.3(a).

TRANS_VALUE =

$$\text{Equation 4.3(a)}$$

1.096–0.023×ACRE+0.965×BUS+1.679×RAIL

   However, this equation is the one to predict values using transformed data.

Thus, the actual predicted values can be calculated with Equation 4.3(b).

VALUE =

$$\text{Equation 4.3(b)}$$

EXP(1.096–0.023×ACRE+0.965×BUS+1.679×RAIL)

Since the p-values of each parameter in TABLE 4.23 are lower than the

significant alpha value, 0.05, this means that all components to be considered in SSC

#4.1 are significant for predicting the value of the parcels under the given significant

value. This also means that the LEED conditions for the bus stop and the railroad

stations for PTA can significantly affect the predicted values of the parcels. For

reference, all values of VIF to check multi-collinearity between the independent

variables are slightly greater than one but lower than 10. This means there is no multi-

collinearity problem in this model.

TABLE 4.21 Analysis of Variance for the PTA Model

	DF	Sum of SqR	Mean SqR	F Value	P VALUE
Model	3	262.1636	87.3879	39.92	<.0001
Error	256	560.4252	2.1892		
Corrected Total	259	822.5888			

TABLE 4.22 Model Summary for the PTA Model

Root MSE	1.4308	R-Square	0.3508
Dependent Mean	2.0630	Adj R-Sq	0.3431
Coeff Var	69.3574		

TABLE 4.23 Parameter Estimates for the PTA Model

EFFECT	DF	Estim	Std Err	T value	P value	VIF
Int	1	1.0964	0.1436	7.64	<.0001	0
BUS	1	0.9652	0.1826	5.29	<.0001	1.0460
RAIL	1	1.6788	0.1903	8.82	<.0001	1.0067
ACRE	1	-0.0230	0.0068	-3.38	0.0008	1.0415

The graphs in FIGURE 4.51 show that the residual for the transformed data is normally distributed. Thus, this statistical analysis can be reasonably accepted although there are some points which need to be checked in Cook's D chart. However, there is no problem regarding these data.
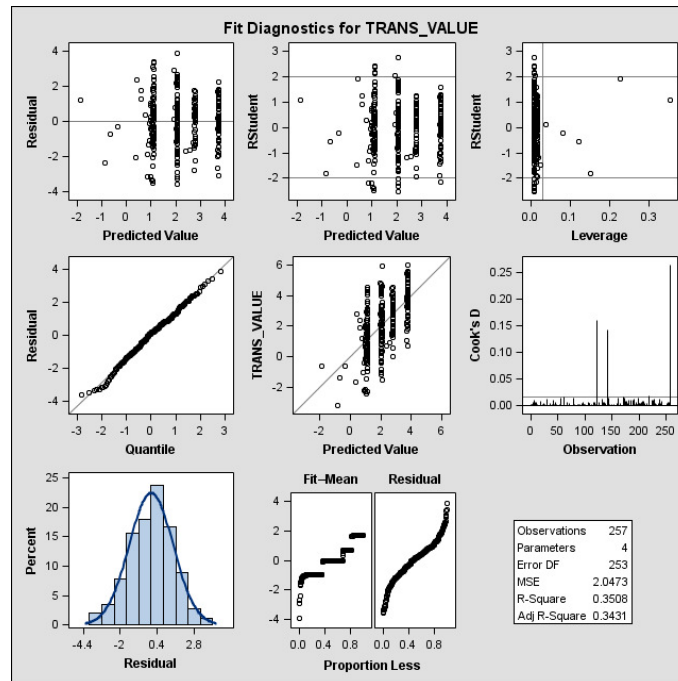
FIGURE 4.51 Transformed Data Fit Diagnostics for the PTA Model

PROC MIXED, PROC GLIMMIX, and PROC REG all show similar results: the p-values for the categorical variables, BUS and RAIL, and continuous variable, ACRE, are lower than 0.05. This means that these factors are significant in predicting the value of unimproved parcels under the significant value alpha 0.05 as shown in TABLE 4.24.

Furthermore, the difference of least square means for the variables, BUS and

RAIL, differ significantly. Thus, the existence of bus stops and railroad stations which

satisfy given conditions in LEED sustainable site selection criteria affect the value of the

unimproved lands as shown in TABLES 4.25 and 4.26. This difference can be verified

with the least means related graphics, diffgrams, as shown in FIGURES 4.52 and 4.53.

Each diffgram has a colorful line rotated by 45 degrees and a reference dashed line. If

the colorful line passed the dashed line, the color of the line must be red. Otherwise, it is

blue. Blue means that the difference is significant statistically. Otherwise, it failed to

conclude that there is meaningful difference statistically under the given alpha value.

According to the colors in FIGURES 4.55 and 4.56, the difference of least square means

for the variables, BUS and RAIL, are significant under the given alpha value, 0.05.

TABLE 4.24 Test of Fixed Effects for the PTA Model

Effect	Num DF	Den DF	F Value	P VALUE
ACRE	1	253	11.43	0.0008
BUS	1	253	27.95	<.0001
RAIL	1	253	77.79	<.0001

TABLE 4.25 shows the estimates for the fixed effects by PROC MIXED and

PROC GLIMMIX analysis. In comparison with the PROC REG analysis, the predicting

equation for each combination of the categorical variables is the same as shown in

TABLE 4.26.

TABLE 4.25 Solution for Fixed Effects for the PTA Model

Effect	BUS	RAIL	Estim	StD ErR	DF	t alue	p alue
Int			3.7404	0.1746	253	21.42	<.0001
ACRE			-0.02294	0.00679	253	-3.38	0.0008
BUS	0		-0.9652	0.1826	253	-5.29	<.0001
	1		0	.	.	.	.
RAIL		0	-1.6788	0.1903	253	-8.82	<.0001
		1	0	.	.	.	

TABLE 4.26 Comparison of Prediction for the PTA Model

Values		Predicting Model	
BUS	RAIL	PROC REG	PROC GLIMMIX AND MIXED
0	0	1.0964-0.0230×ACRE	1.0964-0.0230×ACRE
1	0	2.0616-0.0230×ACRE	2.0616-0.0230×ACRE
0	1	2.7752-0.0230×ACRE	2.7752-0.0230×ACRE
1	1	3.7404-0.0230×ACRE	3.7404-0.0230×ACRE

Finally, the Studentized Residuals by PROC GLIMMIX analysis are also normally distributed as shown in FIGURE 4.52.
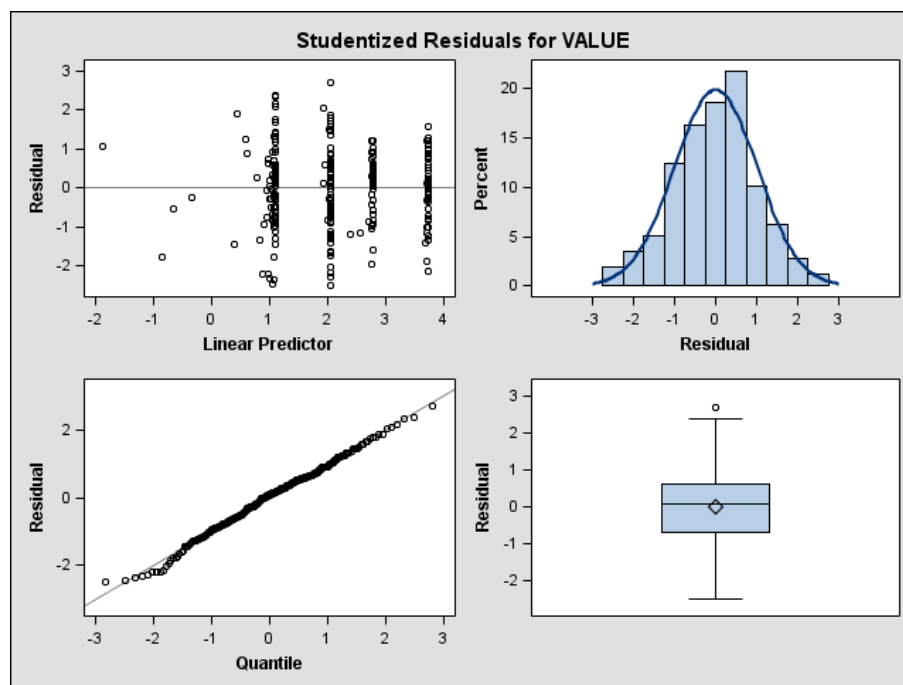
FIGURE 4.52 Residual by Proc Glimmix for the PTA Model

4.3.3.   ANOVA

4.3.3.1. Unit Value Contrasts

FIGURES 4.53-4.57 show the boxplots for the treatment and control group of each criteria and TABLES 4.27-4.31 display the results of tukey's studentized range test between the treatment and control groups of each criteria.

TABLE 4.27 Difference of Least Square Means for the Variable, SSC1

SSC1	SSC1	Estim	Std Err	DF	T Value	p value
0	1	-0.3620	0.3350	281	-1.08	0.2807

FIGURE 4.53 Diffgram for the Variable, SSC1

TABLE 4.28 Difference of Least Square Means for the Variable, SSC3

SSC3	SSC3	Estim	Std Err	DF	T Value	P value
0	1	-0.2590	0.2302	281	-1.13	0.2614
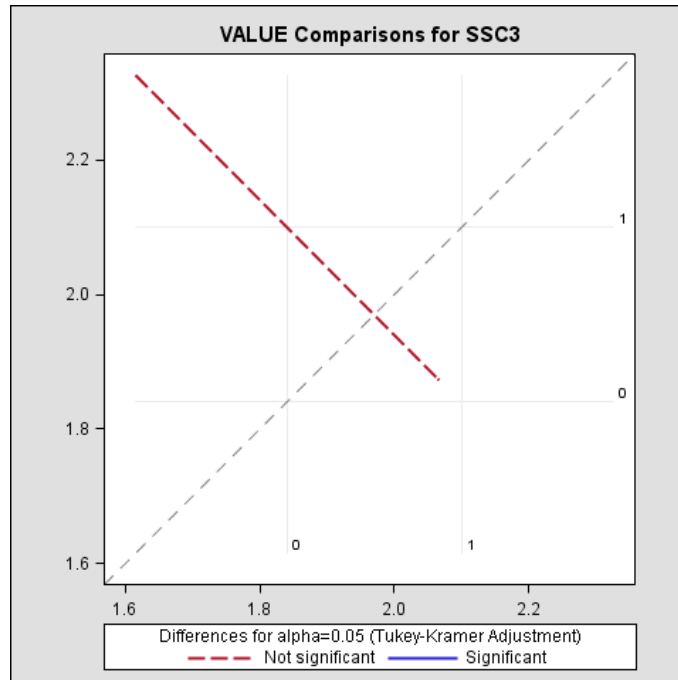
FIGURE 4.54 Diffgram for the Variable, SSC3

TABLE 4.29 Difference of Least Square Means for the Variable, BUS

BUS	BUS	Estimate	Std Err	DF	t value	P value
0	1	-0.9652	0.1826	253	-5.29	<.0001

FIGURE 4.55 Diffgram for the Variable, BUS

TABLE 4.30 Difference of Least Square Means for the Variable, RAIL

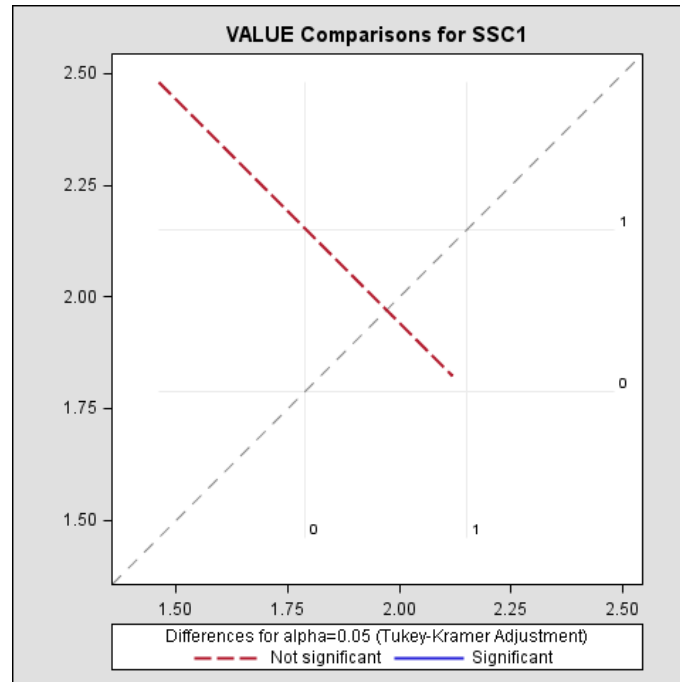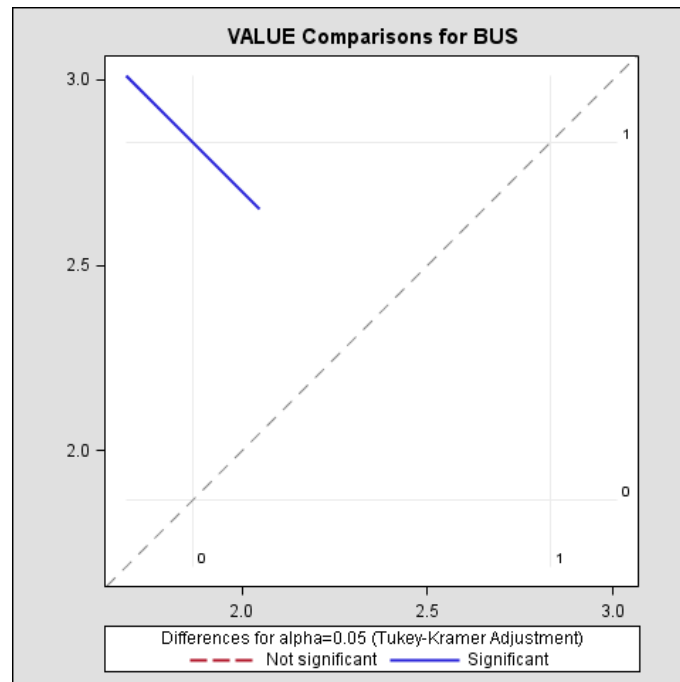| RAIL	RAIL	Estimate	Std err	DF	t value	P value
0	1	-1.6788	0.1903	253	-8.82	<.0001
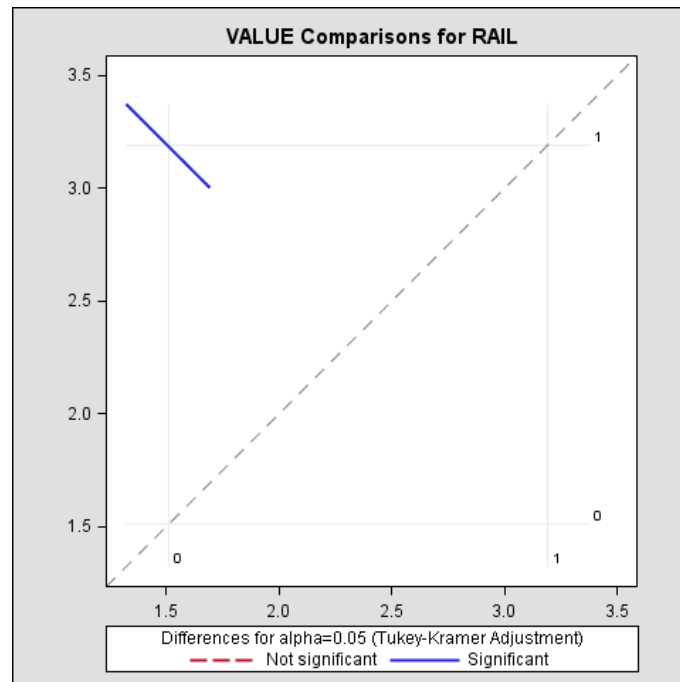
FIGURE 4.56 Diffgram for the Variable, RAIL

TABLE 4.31 Difference of Least Square Means for the Variable, SSC4

SSC4	SSC4	Estim	Std Err	DF	T Value	p value
0	1	-1.0977	0.3265	281	-3.36	0.0009
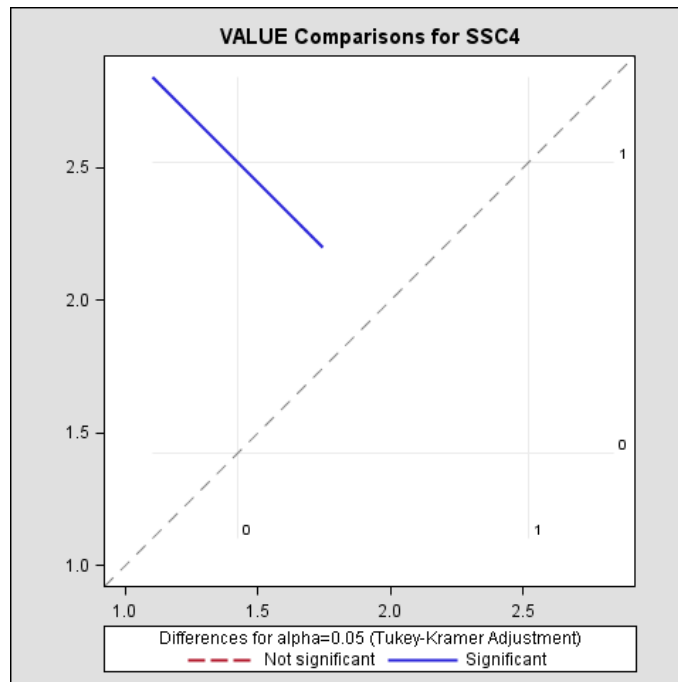
FIGURE 4.57 Diffgram for the Variable, SSC4

4.3.3.2. Interpretation

According to the results above, the mean of unit values for the parcels regarding site selection and brownfield is not significantly different with the one of each control group, respectively. Otherwise, as predicted, the unit value of the parcel which satisfies the condition for the PTA is significantly higher than the ones which cannot satisfy the given condition to obtain sustainable credits. Furthermore, the unit value of parcels

which meet LEED requirements for bus stops and railroad stations of the PTA MODEL

are significantly higher than those in the control group which do not.

CHAPTER V

CONCLUSIONS

Globally, there is a strong trend toward the implementation of green construction methods. Although there are various definitions regarding green construction, the fundamental aim and the basis of this concept is sustainability. Moreover, although it is not easy to define the exact meaning of sustainability, development models that simultaneously pursue environmental preservation and continuing economic benefits can reflect the essential value of this word, sustainability.

In terms of the land development or restoration, sustainable site selection contains definite preconditions that satisfy this dual goal: environmental preservation as well as increased economic benefit. Reflecting this aim, the USGBC have developed a metric, called 'LEED 2009 for New Construction and Major Renovations' for encouraging sustainable land development. Among the criteria in the metric, there are three dealing with sustainable site selection: SSC #1, SSC #3, and SSC #4.1.

It is important to observe that there is little scientific evidence to support USGBC's argument for sustainability in terms of economics. In other words, although it is easy to logically deduce that the metric suggested by USGBC pursues environmental preservation, there is no clear demonstration to show that this metric guarantees sustained economic benefit. Thus, in this study, the author tried to identify if the criteria for sustainable site selection also reflected the economic merits contributed by these criteria to the appraised value of the land by means of linear regression.

5.1.   Model to Predict the Appraisal Value of the Parcel

　　　The models to predict the appraisal value of the parcel with the variables, the LEED criteria/components, were established with multiple linear regression analysis. Unfortunately, the adjusted R-squares in both overall and individual models are respectively 0.2256 and 0.3508, which are relatively lower than expected. This means that there are other factors to affect appraisal value of the parcel. However, in both analyses, the transformed data is normally distributed and the other statistical values reflected the validation of the analyzing process. Furthermore, the three ways to establish the predicting model-PROC MIXED, PROC REG, and PRO GLIMMIX-produced the same results. Thus, it is concluded that the statistical approach in this research is valid and can be accepted reasonably. For increasing the R-square, it may be better to use continuous variables instead of the categorical variables primarily used as well as adding the other possible factors in prediction models.

5.2.   Significance of the Detail Components

　　　According to the results of the statistical analysis in this study, it is concluded that two criteria regarding SSC #1 and SSC #3 were not significant. Namely, two criteria, site selection and brownfield, do not significantly affect the appraised value of land in Houston. However, there may be economic benefits associated with these properties that may not register in the appraised value of the property, such as property tax credits, free environmental inspections, and economic assistance for cleanup. Another possibility is that the positive economic effect for these factors has yet to be recognized in the market.

If this is true, it could mean the economic benefits of these factors are currently available at a discount to future valuations. Time will tell.

On the other hand, the criteria regarding PTA was a significant factor in the overall model predicting land appraised values. Furthermore, detail component conditions regarding bus stops and light rail stations were also significant factors in the individual model to predict land appraised value. The results may be one of the most essential outcomes through this research. The light rail station factor was more highly significant than bus stops. It may be concluded that PTA can assist environmental preservation by discouraging the development of land which is far from PTA. It also enhances sustained economic benefit by increasing the development density near public transportation corridors.

5.3. Formalized Process Using GIS

Through this research, the process to obtain data which are necessarily required to estimate the LEED credits of the undeveloped sites using GIS was established. With this methodology, it may be valuable to compare outcomes for the other cities in Texas such as Dallas, Austin, and San Antonio using the same methodologies and to suggest a more general predicting model for cities in Texas. Furthermore, it also may be possible and instructive to compare Houston, a city with an immature public transportation system, to a city such as New York or Portland with this formalized process.

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VITA

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