IMPACT OF ACCESSIBILITY TO RAIL TRANSIT ON COMMERCIAL PROPERTY VALUES: A CASE STUDY OF THE MIAMI METRORAIL

By

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To my Mom

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Transit-joint development (TJD) is a popular way to finance transit systems, to support transit-oriented development (TOD) and to address many urban problems through public-private partnerships. TJD partnerships between commercial development and fixed-rail transit systems are usually based on the important premise that accessibility provided by a rail transit system coupled with a stimulated higher population movement may benefit businesses around transit stations, which can then be captured in commercial property values around them. However, no agreement has been reached by studies concerning the relationship between accessibility to rail transit and commercial property values. Global models applied in those studies failed to account for spatial nonstationarity and sometimes could not provide sufficient justifications for either policy makers or business owners to decide whether to turn down or to participate in rail transit-joint development projects.

Geographically Weighted Regression (GWR) has the ability to capture spatial variance in relationships between dependent variables and explanatory variables. By applying ordinary least square (OLS) and GWR in Miami-Dade County, the study found that accessibility to Miami Metro Rail stations has a significant impact on commercial

land values. The results of OLS model indicated that county-wide if a property sits one mile closer to metro rail stations, this is associated with a $1.92 per square foot decrease in commercial property values. However, GWR revealed that this impact varies significantly throughout the geographic study area. Metro stations in the north are associated with decreasing commercial property values, while those in the south are associated with increasing commercial property values. The increase in value for some properties if situated even one mile closer to some metro stations could be as high as $22 per square feet. With a mutual recognition of this property value increment, public-private partnerships between the rail transit agency and commercial developers could be built to achieve a win-win situation. On the contrary, incentives such as density bonus or favorable rates should be given to business owners if commercial development has to be encouraged in an area where construction of rail transit is associated with decreasing property values. When investigating the relationship between accessibility to rail transit and commercial property values, GWR is a more suitable model than OLS to support decision-making processes that fully utilize metro stations' value capture potentials.

CHAPTER 1
INTRODUCTION

Location, location, location! – Both home owners and business managers receive this key advice when considering where to purchase properties. Location matters for many reasons; one of the most important is accessibility. For businessmen, accessibility refers to the ease with which their offices or stores can be reached by customers and employees. A property's accessibility is affected by both its physical proximity to a desirable location and the capability of transportation facilities connecting those (Smith & Gihring, 2006). Besides highways, public transit systems, especially fixed rail systems like metro rails and light rails, also play important roles in improving accessibility for businesses around transit stations.

In recent years, public-private joint projects have become a popular way to finance rail transit systems. Businesses are encouraged to locate near transit stations because sources suggest that they could benefit from transit-oriented development (TOD) nearby to reduce transportation costs for employees, to attract more customers for business, and to enjoy the stimulated economic development in a cluster pattern (Smith & Gihring, 2006). Such accessibility advantages would be capitalized into higher commercial property values. Based on the promise of transit system's value capture potentials, more and more transit agencies are seeding financial support from the private sector in the form of commercial transit-joint development. However, proximity to transit systems could have negative effects on commercial property values due to increased crime, induced traffic, noise levels and air pollution. Developers are concerned that the advantages of enhanced accessibility are offset by the cost of other negative impacts, and locating their commercial development near a transit system may not gain as much benefit as they expected.

Moreover, studies concerning the impact of rail transit stations on residential property values have revealed that such impacts are not spatially consistent. The impact of rail transit accessibility on residential property values is positive in some areas while it is negative or has no effect on other areas (Du and Mulley 2006). Although many studies have investigated the relationship between accessibility to rail transit system and commercial property values, the issue of spatial nonstationarity in this relationship remains unexplored. Although a global model may show that in the whole study area a transit system has an average positive impact on commercial property values, it is still possible that it has negative impact on commercial properties in certain subareas. Without accounting for the spatial variation of metro rail stations' value capture potential, commercial transit-joint development could be built in the wrong places and fail to fully utilize transit stations' value capture potentials.

Opened in 1984, the Miami Metrorail is the only heavy rail rapid transit system in Florida. The system is composed of two lines of 23 stations on 24.4 miles (39.3 km) of standard gauge track. Examining its impact on property values would be helpful for other TJD projects involving commercial development in Florida. By applying the Hedonic price model and geographically weighted regression, the study aims at testing the impact of Miami Metro Rail stations on commercial land values to address the questions raised by business owners, developers, and policy makers: Dose accessibility to rail transit have significant impact on commercial property values in Miami-Dade County? Does this impact vary significantly over space? If it does, where does the metro rail have the greatest potential of value capture if commercial transit joint developments occur? And what are the possible reasons for spatial variation of this impact? Last but not least, is Geographically Weighted Regression a more suitable model for the purposes of this study than Ordinary Least Square?

Figure 1-1. Miami-Dade metro rail system. Adapted from Miami-Dade Government website, Retrieved August 1st, 2014, from http://www.miamidade.gov/transit/library/metrorail-map.pdf /. Copyright 2014 by Miami-Dade Transit. Reprinted with permission.

CHAPTER 2
LITERATURE REVIEW

Transit-Oriented Development (TOD) and Transit-Joint Development (TJD)

Transit-oriented development (TOD) is popular among policy makers and planners as a strategy to address urban problems, such as traffic congestion, air pollution, affordable housing shortage, declining downtown and urban sprawl. Compared to a bus transit system, fixed-rail transit systems have gained popularity among passengers as alternatives to automobiles because of their greater capacity and faster speed. However, building rail transit systems is expensive. The capital investment to create a rail transit system project is huge and could still be a financing burden for transportation agencies or local governments after years of operation. Due to deep cuts in federal transit assistance, transit-joint development (TJD) has become a popular way to finance transit systems, especially fixed-rail transit systems, through public-private partnerships. According to the Federal Transit Administration (FTA):

> Joint Development refers to the development of real property that was purchased with FTA funds. More often than not, this real property is developed while maintaining its original public transportation purpose. This is done by placing residential, commercial, or community service development on, above, or adjacent to property that was purchased with FTA funds. Joint Development may include, but is not limited to, the following:
>
> Commercial and residential development;
>
> Pedestrian and bicycle access to a public transportation facility;
>
> Construction, renovation, and improvement of intercity bus and intercity rail stations and terminals;
>
> And renovation and improvement of historic transportation facilities (Federal Transit Administration Guidance on Joint Development, 2014, p.7).

Similarly, Cevero (1994) defined transit-joint development as:

> Any formal, legally binding arrangement between a public entity and a private individual or organization that involves either private-sector payments to the public entity or private sector sharing of capital or operating costs, in mutual recognition of the enhanced real estate development potential or higher land values created by the siting of a public transit facility(Cevero, 1994, p.1).

TJD projects usually try to achieve “win-win” outcomes through public-private partnerships in which participants in the private sector provide financial support to transit systems in the form of cost-sharing or revenue-sharing. The former includes sharing the cost of station construction, excavation, parking lots and other facilities. The latter includes air rights and property leasing, connection fees or benefit-assessment financing (Cevero, 1994). In return, transit agencies provide incentives to private developers, including density bonuses and favorable rates. In order to attract private participants, an important premise on which TJD is based is that the enhanced accessibility provided by the transit system, together with the higher densification population movement, would lead to higher property values around stations, which will benefit both businesses and residents in joint development areas. If this assumption exists in Miami-Dade County, commercial public-private partnerships could be built to assist rail transit development by building commercial development near metro stations; if it does not, rail transit agencies should seek financial support from other sources.

Overview of Empirical Study Results

Although widely discussed by the public and academic researchers, no agreement on the relationship between transit rail systems and commercial property values has been reached. Findings from literature concerning the impact of proximity to transit rail on commercial property value vary in respect to the direction and degree of the impact. Some literature found that commercial property closer to a rail transit station have higher property values than those farther away (Cevero and Duncan 2002; Weinberger 2001; Debrezion, Pels and Rietveld 2007). These findings support the point that rail transit stations could attract commercial activities and high population movement, which generates value premiums on commercial properties (Debrezion, Pels and Rietveld 2007).

On the other hand, some studies found no statistically significant impact of proximity to transit rail systems on commercial property values (Falcke 1978; Landis 1994). Additionally, there are studies which suggest that the benefit of proximity to transit rail systems were offset by other induced negative impacts, such as noise and crime. As a result of these negative effects, property values could actually be lower near rail stations (Lerman et al. 1978; Cervero and Duncan 2002).

Beside the variation in directions, the impact of rail transit systems on commercial property value also varies by the types of rail systems. Among literature concerning this issue, light rail systems are most likely to have positive impacts on surrounding commercial properties, while the impacts from heavy rail systems and commuter rails are usually mixed. They could be positive, negative or have no effect. The extent of the impact from different types of rail systems also varied. A study conducted in Los Angeles County found that heavy rail transit systems have greater positive effect on property values than light rail systems; situating within ½ mile of a subway station has a premium of $272,451.7 in commercial property sales price, while the premium of being within ¼ mile of a light rail station is $14,876.6 (Cevero, 2002).

Additionally, the rail transit system has different impacts on commercial property values and on residential properties. Some studies have revealed that commercial and office properties benefit more from their proximity to rail transit systems than residential properties (Cevero, 2002; Debrezion, 2007). Other research indicated that transit accessibility has a negative impact on residential property values, while it has no effect on commercial properties (Landis et al. 1995).

Table 2-1. Summary of literature: impact of rail transit accessibility on commercial property values

Year	Author	Study Region	Rail	Methods	Significance
1978	Lerman et al.	Washington, D.C.	HR	Hedonic	- ns
1995	Landis et al.	Alameda County	HR	Hedonic	ns
1996	Landis et al.	Contra County	HR	Hedonic	ns
2001	Weinberger	Santa Clara County, California	LRT	Hedonic	+
2002	Cervero and Duncan	Santa Clara County, California	LRT CR	Hedonic	+ +
2002	Cervero and Duncan	Los Angeles County	HR LRT CR	Hedonic	- + +/-
2002	Cervero and Duncan	San Diego County	LRT CR	Hedonic	+ -
2002	Weinstein and Clower	Dallas	LRT	Comparison	+
2007	Debrezion, Pels & Rietveld	n/a	HR LRT CR	meta-analytical procedures	+ + +

HR: heavy rail transit system

LRT: light rail transit system

CR: commuter rail transit system

+: positive impact

-: negative impact

ns: not significant

Hedonic Model for Commercial Land Value Estimation

The hedonic pricing model is widely considered by many researchers as a suitable model to investigate the marginal contribution of various attributes to the value of a commodity (in this case, commercial property values). The hedonic model usually takes the form:

$$P_i = \int(T, N, L, C) \quad 2\text{-}1$$

Where

$P_i =$ Estimated property price of parcel i,

T = vector of transportation accessibility,

N = vector of neighborhood characteristics,

L = vector of regional accessibility attributes,

C = vector of other factors.

The hedonic pricing model considers the property value of a parcel as a function of all attributes affecting it. Transportation accessibility is usually represented by dummy variables indicating whether a parcel is within a certain distance to a public transit station or highway interchange. Neighborhood characteristics usually include density, median household income, and median building value within a certain distance radius of a parcel. Distance to downtown and accessibility to jobs are commonly used variables for regional accessibility attributes. The most important advantages of the hedonic pricing model is that every parameter estimated indicates the degree of change in a dependent variable caused by one unit change in the corresponding independent variable. For example, the coefficient of distance to downtown could show the amount of property value change when locating one unit (e.g., one mile) closer to downtown.

The Problem of Spatial Nonstationarity

Just like any other “global” model, the hedonic pricing model assumes that relationships between dependent variables and explanatory variables are constant across a study region, which is not usually the case in reality. For example, the hedonic pricing models assume that wherever the property is located, the marginal price increase associated with one additional free parking space is fixed. However, this may not be true. It is reasonable to assume that rates of change in property values are determined by local characteristics rather than by a universal factor and that there may be an intrinsic difference in relationships over space (Brunsdon et al. 1996). The marginal price increased by an additional free parking space may be greater for commercial properties in a downtown area where free parking is limited than for those in suburban areas where free parking spaces are abundant. Such variation in relationships over space is called spatial nonstationarity (Brunsdon et al. 1996). Applying global models (e.g. hedonic pricing models) to examine relationships with spatial nonstationarity is misleading. Because relationships could be positive in one area and negative in the other, fitting a uniform linear function to the whole study region could have a “cancellation” effect and could lead to overestimation, underestimation or non-significant results in a large study area.

Geographically Weighted Regression

Geographically weighted regression is an extension of the traditional global regression to capture spatial variations in relationships by allowing coefficients to be estimated locally rather than globally. This local modeling method produces parameter estimates varying over space (Brunsdon et al. 1996; Fotheringham and Brunsdon 1999;

Fotheringham et al. 2002). In traditional regression, the equation could be indicated as Equation 2-2; while in a GWR equation it is written as Equation 2-3.

$$y_i = \beta_0 + \sum \beta_k x_{ik} + €_i, \qquad 2\text{-}2$$

$$y_i = \beta_0(u_i, v_i) + \sum \beta_{ik}(u_i, v_i) x_{ik} + €_i \qquad 2\text{-}3$$

Where

y_i = the ith observation of the dependent variable,

x_{ik} = the ith observation of the kth independent variable

β_k = coefficient of the kth parameter,

β_{ik} = coefficient of the kth parameter at location i,

$€_i$ = error

As described above, traditional linear regression models assume that relationships between dependent variables and explanatory variables are constant over space, using uniform equations for the entire study region and treating all observations equally. Unlike traditional regression models, GWR analyzes each point (u_i, v_i) in the dataset separately, incorporating the dependent and explanatory variables close to the estimated point (u_i, v_i). GWR does this by weighting every observation according to its proximity to an estimated point. By putting more credits on observations closer to the estimated point, observations near the estimated point have a greater impact on the coefficient estimation while observations that are very far away from the estimated point have weights approximated to zero and could be considered excluded from the analysis of the estimated point. When applied to a large dataset, GWR is able to generate local functions of dependent variables and explanatory variables across the study region by using only a subset of data that are close to each point. For the purpose of this study, it is appealing to apply GWR to the land market to develop a unique marginal effect of rail transit accessibility on commercial property values in different locations.

GWR has not been widely used to analyze property values yet. Several studies that are aware of the problem of spatial nonstationarity on land markets applied GWR only to residential properties. For example, Du and Mulley (2006) compared results from a typical Hedonic pricing mode and a GWR, and revealed that GWR supported a better understanding of the relationship between transport accessibility and residential land value. In their study, although the global model shows that residential land within 500 meters of a metro station catchment area has £ 10407.59 value premium, the result from GWR shows that there is spatial nonstationarity existing in this relationship; proximity to a transit station generates no value premium in the southwest area of the study region and has a negative impact on land value in some areas that are very close to transit stations. The authors concern that uniform land value capture policy for transit financing is inappropriate; its power of value capture may actually be overestimated in many areas. Similarly, several other studies show that there is spatial nonstationarity existing in the analysis of residential property values (Farber and Yates 2006; Pa´ez 2005; Bitter et al. 2007).

GWR provides a better understanding of variables affecting property values and is a suitable model in terms of explanatory power and predictive accuracy (Bitter et al. 2007). No study was found to apply GWR to the relationship between rail transit and commercial property values. It would be interesting to see whether spatial nonstationarity exists in the variables affecting commercial property values as it is in those affecting residential properties, and if it does how the value capture power of rail transit might vary across the study region.

Summary and Implications for Research

Through public-private partnerships, transit-joint development (TJD) could be a good way to finance transit systems, to support transit-oriented development (TOD) and to address many urban problems. Among all kinds of transit systems, the fixed-rail transit system is one of the most popular candidates for TJD projects because of its high capital investment and great transportation capability. TJD partnerships between commercial development and fixed-rail transit systems are usually based on an important premise, that accessibility provided by a rail transit system together with the stimulated higher population movement would benefit business around transit stations, which would be captured in commercial property values around them. However, no agreement has been reached by studies concerning the relationship between accessibility to rail transit and commercial property values.

One of the reasons for the contradictory results from various research studies may be that the global regression method they applied assumes that the relationship between accessibility to rail transit and commercial property value is constant over space; it does not account for nonstationarity issues that may exist in the real world. If a rail transit system has a positive impact on one part of the study area, while having a negative impact on another, applying a global regression model on the entire study area may have a “cancellation effect” (Du, H., & Mulley, C. 2006) and lead to globally non-significant or only slightly significant results. It is possible that, due to the global regression mode, greater impacts of the rail transit system on commercial property values in part of the study area are hidden, as are the opportunities for establishing public-private partnerships to achieve a win-win outcome. If the impact of rail transit systems on commercial property values varies over space, as the study has assumed, results from global regression models could not provide sufficient justification for either policy makers or business owners to decide whether to turn down or to participate in rail transit-joint development projects. They would also not be able to make informed decisions on location choices and types of incentives for different joint-developments according to their geographic locations. Therefore, it is necessary to examine the relationship between the rail transit system and commercial property values locally rather than globally.

Geographically Weighted Regression (GWR) has the ability to capture spatial variance in relationships between dependent variables and explanatory variables. Instead of providing a generally average impact of rail transit on commercial property values, GWR could give details about where commercial properties could benefit from sitting closer to a metro rail system, and where their proximity to rail stations is associated with decreasing property values. The model could also examine how the extent of such impacts varies by geographic locations. These advantages of GWR make it a suitable candidate to test whether there is spatially nonstationarity existing in relationships between rail transit systems, and if there is, how the GWR result could improve our understanding about the impact of rail transit systems on commercial property values and the decision-making process about transit-joint development projects.

CHAPTER 3
METHODOLOGY

This research aims to investigate the relationship between rail transit accessibility and commercial property values in Miami-Dade County. The research is cross-sectional, retrospective and quasi-experimental. Both the hedonic pricing model and Geographically Weighted Regression model were applied to investigate the impact of accessibility to Miami metro rail stations on commercial property values. Study objects consisted of all commercial parcels in Miami-Dade County. Data used in the research includes digitized Miami Metro Rail Stations, land values and land use data in parcel 2010 data from the Florida Geographic Data Library (FGDL), infoUSA employment data which provides geocoded locations and number of employees for all worksites and census block 2010 data. Results from global and local models were compared to find out whether there is a spatial nonstationary relationship between dependent variables and explanatory variables, and if it is, how such spatial variations would affect the value capture power of transit joint development of the Miami metro rail.

Table 3-1. List of data and sources

Data	Sources
Miami metro rail station locations	Digitized
Highway interchanges and street intersections	FGDL
Commercial Land Value, land use and other characteristics	FGDL parcel 2010
Neighborhood socio-demographic data	Census block 2010
Employment types, locations of worksites and employee numbers	Info USA

Model Development

Hedonic Pricing Model

The study first applied the hedonic pricing model using a global OLS linear regression structure. The linear model structure could be described as followed;

$$y_i = \beta_0 + \beta_{TA}X_{iTA} + \beta_{SES}X_{iSES} + \beta_{NL}X_{iNL} + \beta_C X_{iC} + \varepsilon_i \quad \text{3-1}$$

Where

y_i = Estimated property price of parcel i,

X_{iTA} = Vector of transportation accessibility variables of parcel i,

β_{TA} = Coefficient of transportation accessibility variables,

X_{iSES} = Vector of socioeconomic variables of parcel i,

β_{SES} = Coefficient of socioeconomic variables of,

X_{iNL} = Vector of neighborhood characteristics and location variables of parcel i,

β_{NL} = Coefficient of neighborhood characteristics and location variables,

X_{iC} = Vector of other factors of parcel i,

β_C = Coefficient of other variables,

ε_i = Residual of parcel i.

An additional variation of the linear-linear regression model, a log-linear model, is developed for further coefficient interpretation. Additionally, the log-linear model could improve model fit when residuals are not normally distributed. In the log-linear model, a nature logarithm of the commercial property value is used as a dependent variable while all explanatory variables remain the same as the base linear model. The log-linear model structure could be described as followed:

$$Ln(y_i) = \beta_0 + \beta_{TA}X_{iTA} + \beta_{NCH}X_{iNCH} + \beta_{RA}X_{iRA} + \beta_C X_{iC} + \varepsilon_i \quad \text{3-2}$$

$Ln(y_i)$ is the natural logarithm of the commercial property value of parcel i and all other parameters remain the same as the base linear-linear model. Coefficients (e.g.β_{TA}) could be interpreted as one unit change in an independent variable (e.g. X_{iTA}) which would lead to a 100β_{TA}% change in the dependent variable.

Geographically Weighted Regression Model

In order to model spatially varied relationships among dependent variables and independent variables, a GWR model was developed to allow the coefficient to vary across the study region. Predicted values and coefficients are estimated for each unique geographic location(u_i, v_i) of a parcel. The GWR model structure could be described as follows；

$$y_i = \beta_0 + \beta_{TA}(u_i, v_i)X_{iTA} + \beta_{SES}(u_i, v_i)X_{iSES} + \beta_{NL}(u_i, v_i)X_{iNL} + \beta_C(u_i, v_i)X_{iC} + \varepsilon_i \quad \text{3-3}$$

Where

$\beta_{TA}(u_i, v_i)$ = Coefficient of transportation accessibility variables at parcel i,

$\beta_{SES}(u_i, v_i)$ = Coefficient of socioeconomic variables at parcel i,

$\beta_{NL}(u_i, v_i)$ = Coefficient of neighborhood characteristics and location variables at parcel i,

$\beta_C(u_i, v_i)$ = Coefficient of other variables at parcel i.

Other parameters remain the same as the base model.

Data and Variables

Descriptive statistics and definitions of dependent variables and explanatory variables used in the hedonic pricing model are presented in Table 3-2. The dependent variable is the commercial property value in dollars per square feet. Explanatory variables are presented in four groups: transportation accessibility, socioeconomic attributes, neighborhood characteristics and other control variables. Statistical mean and standard deviations were shown for numeric variables, while the proportions of a category in the total dataset were presented for nominal variables.

Transportation accessibility includes accessibility to the Miami metro rail, bus transit and highway networks. Accessibility to the Miami Metro Rail and bus transit system were measured by the network distance to the nearest metro rail station or bus stop from every parcel. Accessibility to the highway was measured by the network distance to the nearest highway interchange. The hypothesis is that having good transportation accessibility would increase commercial property values but such a benefit would decrease in areas that are too close to or too far away from transit stations and highway interchanges. The study also expected that different types of transportation systems would have different extents of impacts on commercial property values.

Socioeconomic attributes include population density and employment within a one mile radius of a commercial parcel. In ArcGIS 10.2, population data from census block2010 and employment data from infoUSA were spatially joined with parcel data applying the condition that census blocks and employment data points are within one mile radius of a parcel. Population density and employment data were then summarized for every parcel. It is expected that high population density and a cluster of commercial and service employment would increase commercial property values while clusters of industrial employment would tend to lower them.

For neighborhood characteristics and location, the study used average building value per acre within a 1 mile radius of a parcel, median household income within a 1 mile radius of a parcel, number of intersections within a 1 mile radius of a parcel and network distance to downtown Miami. The hypothesis is that the higher the average building value and median household income in the neighborhood, the higher the commercial property value. Additionally, having more intersections and being closer to downtown are expected to increase commercial property value.

The hedonic price model was conducted to test the impact of all the independent variables on commercial land values. Geographic Weighted Regression was used to investigate spatial variations of coefficients.

Table 3-2. Descriptive statistics and definitions of variables

Variables	Mean/ proportion	Standard Deviation
Dependent Variable:		
Commercial land value per square feet	41.14	50.53
Location & Accessibility Variables:		
Network distance to the nearest Metro Rail station(mile)	4.35	4.26
Network distance to the nearest bus station (meter)	144.42	552.13
Network distance to the nearest highway interchange(mile)	4.42	3.28
Network distance to downtown(mile)	6.15	5.81
Socioeconomic Variables:		
Average population density within 1 mile radius of a parcel	15.90	6.21
Commercial employment within 1 mile radius of a parcel	3760.47	2756.85
Service employment within 1 mile radius of a parcel	9662.63	9999.03
Industrial employment within 1 mile radius of a parcel	1097.64	1180.20
Neighborhood Characteristics:		
Median household income within 1 mile radius of a parcel	42115.73	16764.12
Number of intersections within 1 mile radius of a parcel	220.58	92.78
Average building value per acre within 1 mile radius of a parcel	627,316.06	836,253.91
Other Variables:		
Parcel size (square feet)	42421.09	166853.61
One-story stores (1= yes, 0 = no)	0.52	--
Restaurants (1 = yes, 0 = no)	0.13	--
Shopping Centers (1= yes, 0 = no)	0.09	--

CHAPTER 4
RESULTS

Hedonic Pricing Model Results

Linear-linear Model

Generally speaking, the hedonic pricing model has explained 54% of variations of commercial property values in Miami-Dade County. The probability of Koenker (BP) Statistic equals zero at 95% confidence level, indicating that there is heteroscedasticity and/or nonstationary results existing in the model, which means that the relationships between the dependent variable and explanatory variables are not consistent throughout the dataset or across the study region. The result of the linear-linear hedonic pricing model is presented in Table 4-1. The coefficient could be interpreted as the unit change in a dependent variable caused by one unit changed of explanatory variables.

Two out of three transportation accessibility variables have significant impact on commercial property values. Both network distance to metro rail stations and highway interchanges have a positive coefficient, indicating that being further away from metro rail stations and highway interchanges would decrease commercial property values. The results indicate that a one mile increase in the network distance from the nearest metro rail station and a highway interchange would increase the commercial property value by $1.91 and $1.23 per square feet, respectively. The distance to bus stations had no significant impact on commercial property values.

All socioeconomic variables are significant. As expected, population density, and commercial and service employment have a positive impact on commercial property values while industrial employment has a negative impact. A commercial property value would increase by $0.499 per square feet if the average population density within a one mile radius increases by one person per acre. Every one thousand new commercial and service employees hired within a one mile radius of a commercial parcel would increase its value by $9 and $1 per square foot respectively. Commercial property values would be decreased by $11 per square foot for every one thousand new industrial workers around it.

Four variables describing neighborhood characteristics and location of commercial parcels show significant impact on property values. Consistent with this hypothesis, average building value and median household income within a one mile radius have a positive impact on commercial property values. A one dollar increase in average building value surrounding the commercial parcel would lift up its property value by $0.3 per square feet. All else being equal, commercial properties are $10 per square feet more expensive when households within one mile radius of them have $10,000 or more annual income. Proximity to downtown has a positive impact on commercial values; being one mile closer to downtown would increase commercial property values by $2.13 per square feet. Contrary to what was expected, the number of intersections around a commercial property had a negative impact on property value; values of commercial properties are higher in areas with more intersections than in those with fewer intersections.

Parcel size has a slightly negative impact on commercial property values; every 10,000 increase in parcel size would decrease the property value by $1.8 per square feet. Additionally, commercial properties that are zoned as shopping centers or department stores are $6.49 cheaper per square feet than other commercial land uses.

Table 4-1. Linear-linear hedonic pricing model summary

Variables	Coefficient	Robust StdError	Robust Probability
Location & Accessibility Variables:			
Network distance to the nearest Metro Rail station (mile)	1.917	0.222	0.000
Network distance to the nearest bus station (meter)	0.000	0.001	0.903
Network distance to the nearest highway interchange (mile)	1.323	0.159	0.000
Network distance to downtown (mile)	-2.315	0.170	0.000
Socioeconomic Variables:			
Average population density within 1 mile radius of a parcel	0.499	0.070	0.000
Commercial employment within 1 mile radius of a parcel	0.009	0.000	0.000
Service employment within 1 mile radius of a parcel	0.001	0.000	0.000
Industrial employment within 1 mile radius of a parcel	-0.011	0.000	0.000
Neighborhood Characteristics Variables:			
Average building value per square feet within 1 mile radius of a parcel	0.303	0.032	0.000
Median household income within 1 mile radius of a parcel	0.001	0.000	0.000
Number of intersections within 1 mile radius of a parcel	-0.028	0.007	0.000
Other Variables:			
Parcel size (square feet)	-0.000018	0.000	0.000
One-story stores (1= yes, 0 = no)	1.612	0.931	0.083
Restaurants (1 = yes, 0 = no)	-1.235	1.265	0.329
Shopping Center (1= yes, 0 = no)	-6.494	1.637	0.000
Summary Statistics:			
Number of Observations = 7305			
AIC = 70793			
AdjR-Squared = 0.54			
F-Stat(Prob) = 569.23(0.00)			
Wald(Prob) = 4233.66(0.00)			
K(BP)(Prob) = 1148.97(0.00)			
JB(Prob) = 34947.12(0.00)			

Log-linear Model

The log-linear hedonic pricing model has better overall performance than the linear-linear model, indicated by an increase in adjusted R-squared rate (from 0.53 to 0.57) and a significant decrease in Akaike's Information Criterion (AIC) value (from 70793 to 13902). The model has explained 57% variance of commercial property value in Miami-Dade County. Lower AIC value shows that the log-linear model has better fit than the previous linear-linear model. However, the probability of Koenker (BP) Statistic equals zero at 95% confidence level still indicates that there is heteroscedasticity and/or nonstationary values existing in the log-linear model. And the probability that the Jarque-Bera Statistic equals zero implies that model residuals are not normally distributed. The result from the log-linear hedonic pricing model is presented in Table 4-2. In the log-linear hedonic pricing model, coefficients could be interpreted as the percentage change in a dependent variable caused by one unit change of independent variables.

In the log-linear hedonic pricing model, all three transportation accessibility variables are significant at 95% confidence level. Locating the property one mile closer to metro rail stations and highway interchanges would decrease commercial property values by 1.05% and 2.81%, respectively. Network distance to bus stations, which is not significant in the previous model, shows a slightly negative impact on commercial property values; locating one mile closer to bus stations would increase commercial property values by 0.026%.

All socioeconomic, neighborhood characteristics and location variables are significant at a 95% confidence level. All of them show the same direction of effect as they did in the previous linear-linear model except for the number of intersections within a one mile radius of a commercial parcel. Clusters of population, commercial and service employment, high average building values and median household income within a one mile radius and proximity to downtown tend to raise commercial property values while clusters of industrial employment tend to reduce it. The number of intersections within a one mile radius of a parcel, which has a negative impact on commercial property values in the previous linear-linear model, shows a slightly positive effect in the log-linear model; commercial property values would increase by 0.07% for every single new intersection added within a one mile radius of it.

Differences are also shown in land use variables. One-story stores and restaurants have a significant positive impact on commercial property values; all else being constant, commercial properties zoned for one-story stores and restaurants are 18.4% and 21.9% more expensive than those that are not. A shopping center is no longer significant.

Geographically Weighted Regression Results

According to the results from two previous global models, Miami metro rail stations have a negative impact on commercial property values. However, both models indicated that there is a nonstationarity value existing in the relationship between network distance to metro rail stations and commercial property values across the dataset or across the study region. In order to investigate spatial nonstationarity in the relationship between the metro rail station and commercial property values, a linear-linear GWR model was developed to allow coefficients to vary spatially. Only variables that are significant in previous global models were included in GWR models.

Table 4-2. Log-linear hedonic pricing model summary

Variables	Coefficient	Exp(coef)-1	Robust StdError	Robust Probability
Location & Accessibility Variables:				
Network distance to the nearest Metro Rail station (mile)	0.01044	1.0496%	0.004	0.009
Network distance to the nearest bus station (meter)	-0.00026	-0.0260%	0.000	0.000
Network distance to the nearest highway interchange (mile)	0.02770	2.8091%	0.003	0.000
Network distance to downtown (mile)	-0.02593	-2.5600%	0.003	0.000
Socioeconomic Variables:				
Average population density within 1 mile radius of a parcel	0.02214	2.2386%	0.002	0.000
Commercial employment within 1 mile radius of a parcel	0.00013	0.0131%	0.000	0.000
Service employment within 1 mile radius of a parcel	0.00001	0.0013%	0.000	0.000
Industrial employment within 1 mile radius of a parcel	-0.00018	-0.0178%	0.000	0.000
Neighborhood Characteristics:				
Average building value per square feet within 1 mile radius of a parcel	0.00570	0.5713%	0.001	0.000
Median household income within 1 mile radius of a parcel	0.00002	0.0019%	0.000	0.000
Number of intersections within 1 mile radius of a parcel	0.00071	0.0709%	0.000	0.000
Other Variables:				
Parcel size (square feet)	0.00000	-0.0001%	0.000	0.000
One-story stores (1= yes, 0 = no)	0.16924	18.4404%	0.020	0.000
Restaurants (1 = yes, 0 = no)	0.19805	21.9018%	0.027	0.000
Shopping Center (1= yes, 0 = no)	0.06197	6.3931%	0.040	0.122
Summary Statistics:				
Number of Observations = 7305				
AIC = 13902.39				
AdjR2 = 0.57				
F-Stat(Prob) = 645.84(0.00)				
Wald(Prob) = 7195.92(0.00)				
K(BP)(Prob) = 280.33(0.00)				
JB(Prob) = 82900.76(0.00)				

The study compared overall performance of global models and GWR models by examining R-squared and AIC values; the former indicates the proportion of variance of commercial property values explained by a model, while the latter shows the model's goodness of fit. Local R-squared and coefficient of explanatory variables were mapped in ArcGIS. Coefficient raster surfaces of network distance to Miami metro rail stations and other explanatory variables were generated using the inverse distance square interpolation method. Multiple-ring buffers of different network distances (0 to ¼ mile, ¼ to ½ mile, ½ to ¾ mile, ¾ to 1mile, 1 to 2 miles and 2 to 4 miles) between commercial properties and metro rail stations were created using the network analysis tool in ArcGIS. A zonal statistics analysis tool was applied to summarize average coefficient values in every ring buffer of every metro rail station. Results from the GWR models are presented in Table 4-3 and Figure 4-1.

The R-squared of the linear-linear GWR model is 0.72, which means the model has explained a 72% variance of commercial property values in Miami-Dade County. The model explanatory power has significantly improved compared to the previous linear-linear global model, which explained 54% of the variance. The AIC index decreased from 70794 to 67089 when using a linear-linear GWR model instead of a linear-linear global model, indicating that the GWR model has overall better explanatory power and goodness of fit than the global model when modeling commercial property values.

From the local R squared map, it is clear that the performance of the GWR model varies across the space. Generally speaking, the model has better performance in south Miami than it has in the northern area. It also has better performance on commercial properties closer to the coast line than on those located inland. The highest R-squared values were observed on commercial properties along US-41 to the east of SR-826, where the median center of commercial property values is located. In those areas, R-squared values range from 0.629 to 0.725, indicating that the local regression has explained up to 72% variations of commercial property values. The model shows moderate performance among commercial properties along I-95 and US-1, R-squared ranging from 0.344 to 0.535. The model's explanatory power is relatively weak in other areas of Miami.

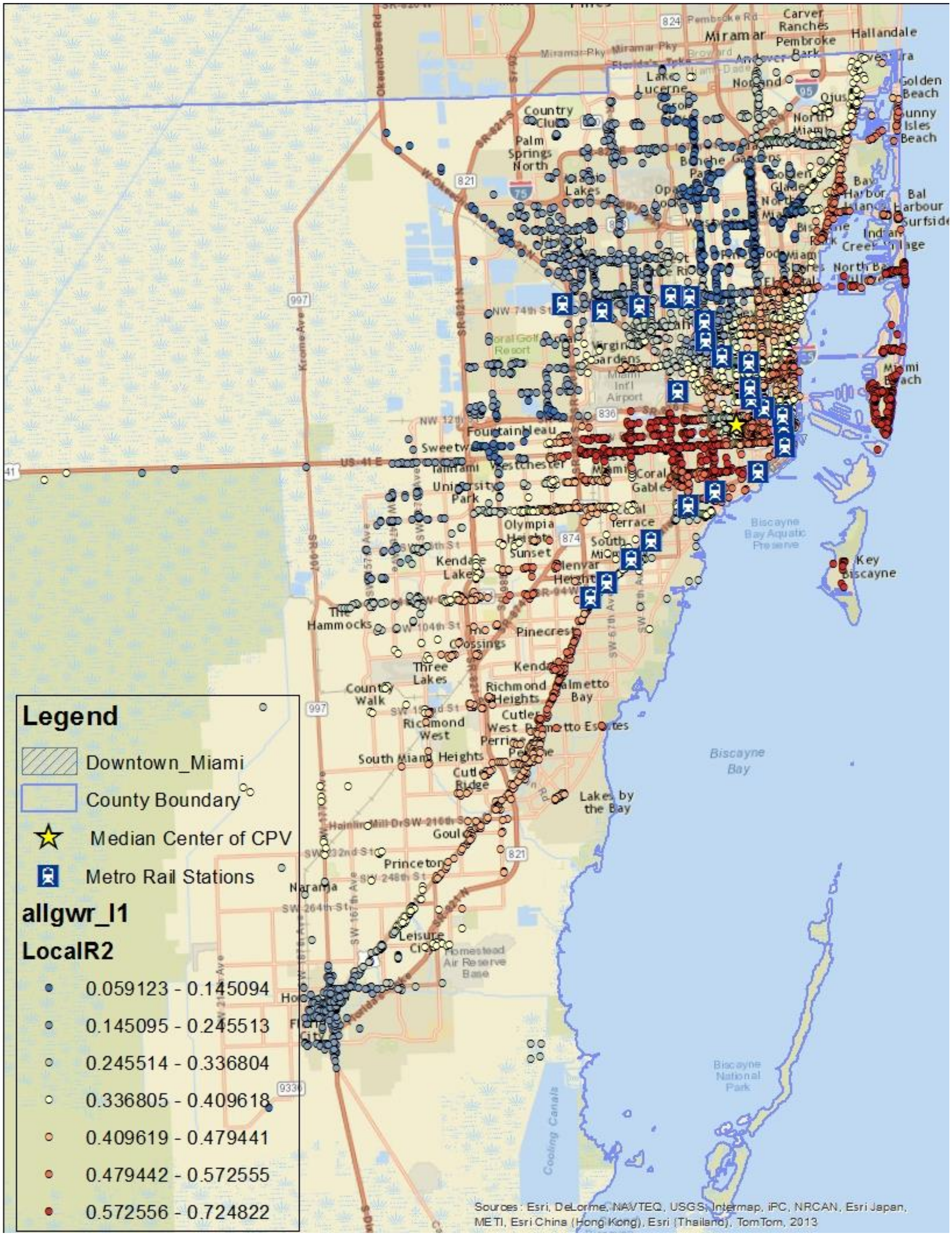

Figure 4-1. Maps of local R-squared values of GWR model

As described earlier, GWR has the ability to examine spatial variations in the relationship between a dependent variable and explanatory variables, which could be hidden in a global regression. In the previous linear-linear global model, network distance to Miami metro rail station has a positive impact on commercial property values; locating property one mile further away from a metro rail station would increase commercial property values by $1.92 per square feet. In GWR, all local coefficients were mapped and surfaces of coefficients were interpolated using an inverse distance weighted method in ArcGIS. Figure 4-1 illustrates the coefficient of network distance to the nearest Miami metro rail station. GWR model analysis was applied to the entire Miami-Dade County, but more emphasis was put on the area within a four-mile network distance buffer of Miami metro rail stations. Zonal statistics in ArcGIS were applied to summarize the average coefficient values of network distance to the nearest metro rail station within various distance buffers (0 to1/4 mile, ¼ to ½ mile, ½ to ¾ mile, ¾ to 1 miles, 1 to 2 mile and 2 to 4 miles.), as Figure 4-4 illustrated. The result of zonal statistics of average coefficient value was shown in Figure 4-5 and Table 4-3.

Figure 4-3 is a raster surface illustrating local coefficient values of network distance to the nearest metro rail station. Positive coefficient was symbolized by the use of orange and red, indicating that proximity to metro rail stations would decrease commercial property values; negative coefficient was symbolized by the colors light to deep green, indicating that proximity to metro rail stations would increase commercial property values. Table 4-3 summarized the average coefficient values within various network distance buffers to metro rail stations, which were sorted by their location from north to south.

The impact of Miami metro rail stations on commercial property values has considerable spatial variation. One of the most obvious trends is that coefficients are positive in most of the areas north of U.S. 41 and are negative south of this highway, indicating that proximity to Miami metro rail stations would decrease values of commercial property in the north area while increasing values of those in the south area. According to Table 4-3, 10 out of 23 metro rail stations located in the southern part of Miami have a positive impact (negative coefficient values) on commercial property values within a 4-mile network distance to them. The other 11 stations in the north have negative impacts on commercial property values.

Two stations have a mixed effect; Vizcaya station has a great positive impact on commercial property values within a 2-mile network distance while it has slightly negative impact on those within a 2 to 4 mile network distance to it. Similarly, the Overtown/Lyric Theatre station would increase commercial property values within a half mile network distance to it while decreasing those located further away. Such even distribution of positive and negative coefficient values among stations may have a cancellation effect when applying a global model and may result in a much smaller average coefficient value. The previous linear-linear OLS model indicated that the coefficient value of network distance to metro rail stations was 1.92, which means proximity to metro rail stations has a slightly negative impact (i.e., they decrease property values by $1.92 for every one mile closer) on commercial property values across the entire Miami-Dade County.

However, as demonstrated in Table 4-3 and Figure 4-3, the extent of such impacts near many stations was much greater than indicated in the global model. For example, the coefficient value within a quarter mile to downtown Brickell station is about -22.34, which means commercial properties in that area have a premium as high as $22.34 per square feet for locating every one mile closer to Brickell Station. Santa Clara Station has a coefficient value of 15.43 on commercial properties within a quarter mile to it, which means commercial property values would increase by up to $15.43 for locating every one mile further away from Santa Clara Station. Although directions are different, in both cases the extent of impact from metro rail stations on commercial property values are much greater than what was indicated in a global regression model ($1.92).

Second, the extent of impact from the metro rail stations decreases when moving from stations near downtown to stations at the ends of the rail. For example, Table 4-3 shows that stations located near downtown have the highest absolute value of coefficients; commercial properties within ¼ mile of three stations located near downtown (Vizcaya, Brickell and Government Center) have value premiums of $17.67, $22.34 and $19.68 per square feet, respectively. The premium decreases when moving to the south. For instance, the premium of property located near Dadeland South Station, which is at the south end of the Miami metro rail, was less than $7 per square feet. The impact of the metro rail station at the north end (Palmetto station) was even smaller; floating from $1.20 to $1.84 per square feet within a 4-mile network distance buffer. One of the reasons for the high premium when located closer to downtown stations may be that such stations have better connectivity to other metro rail stations. It takes less time to travel to all other stations from the midpoint of the rail than from any other station, which makes riding the metro rail more convenient and appealing near downtown stations than others. Additionally, high population density, good street connectivity, as well as easier transfer to other transportation modes in the downtown area also help improve the attractiveness of the metro rail and maximize its positive impact on commercial properties around them.

Moreover, the extent of the impact from Metro rail stations on commercial properties also changes by the distances between them. A total of 4 out of 23 stations show impacts on commercial property values decrease as distances between the two increases from zero to 4 miles; they are Vizacaya Station, Brickell Station, Allapattah Station and Miami International Airport Station. For example, around Brickell Station, the premium of proximity to the metro rail station decreases all the way from $22.34 to $16.79 as the distance between commercial parcels and Brickell Station increases from ¼ mile to 4 miles. Four other stations had impacts on commercial property values which became larger when the distance between them increased; they are South Miami Station, University Station, Brownsville Station and Dr. Martin L King, Jr. Station. Commercial properties within a quarter mile network distance to the South Miami Station have a land value premium of $4.46 per square feet while those located between two miles to four miles have a premium of up to $6.73 per square feet.

The extent of impact from 15 other stations on commercial property values fluctuated as the distance between the station and commercial properties increase from zero to 4 miles. For example, the premium of proximity to Culmer Station decreases from $10.29 to $4.71 as the distance increases from ¼ mile to 2 miles, and it increases to $18.62 as the distance increases from 2 miles to 4 miles. For most metro rail stations, differences between the coefficient values are within $5 per square feet within a 4-mile network distance area. Figure 4-4 shows stations whose coefficient values have changed significantly (> = $5).

Additionally, one station could have a different impact on commercial properties situated in the same distance but in a different direction to it. For example, Dr. Martin Luther King, Jr. Station and Brownsville Station have positive impacts on commercial properties to their east while they have negative impacts on those to their west. Palmetto Station has a positive impact on values of commercial properties to its north while it has a negative impact on values of those to its south.

Beside network distance to the metro rail station, other explanatory variables also showed considerable spatial variation of their impacts on commercial property values in Miami-Dade County. Figure 4-7 to Figure 4-12 are maps of coefficient surfaces of other explanatory variables, which show considerable variance over space. Coefficient values are classified into different color groups; green areas represent variables which have a positive impact on commercial property values while orange and red areas indicate variables which have a negative impact on commercial property values.

In Figure 4-7, industrial employment has a negative impact on commercial property values in most of the study area except in one area near the metro rail corridor from Douglas Road Station to Dadeland South Station, where every 100 new industrial employees within one mile radius of a commercial parcel would increase its value by up to $0.94 per square feet. Industrial employment has the greatest negative impact on the northeast coast and areas along U.S. 41. Every 100 new industrial employees would decrease the value of commercial properties near Coconut Grove Station by $4.4 to $8.4 per square feet.

In Figure 4-8, commercial employment has a positive impact on commercial property values across the study area. However, the extent of such impact varies spatially. The greatest premiums were found on the costal islands and in neighborhoods to the north of downtown, where every 100 new commercial employees added to one mile radius of a commercial parcel could increase its value by up to $3 per square feet.

In Figure 4-9, proximity to highway interchange has the greatest negative impact on commercial properties in the area along U.S. 41 between the coastline and S.R. 826. Locations one mile closer to a highway interchange could decrease commercial property value by $5 to $10 per square feet. Proximity to the highway interchange has the most significant positive impact on commercial properties near downtown and close to the Allapattah, Santa Clara and Civic Center stations; premiums could be as high as $15 per square feet for moving every one mile closer to a highway interchange.

In Figure 4-10, commercial properties zoned for shopping centers have significantly lower value in northeast Miami (to the north of US 41 and to the east of US 27). Along metro rail corridor starting from downtown to Dadeland South station, commercial properties zoned for shopping center have higher value than others. The highest premium was observed near Douglas Road station, which is up to $17 per square feet.

Figure 4-11 shows the coefficient of parcel size. As expected, the larger the parcel, the lower per-square-feet value it is. Additionally, Figure 4-12 illustrates the coefficient of average building values within one mile radius of a commercial parcel. Higher building values around commercial properties could raise property values in most of study area, with exceptions in neighborhood near Bridell and Vizcay stations, where average building value within one mile radius of a commercial parcel could slightly decrease its property value.

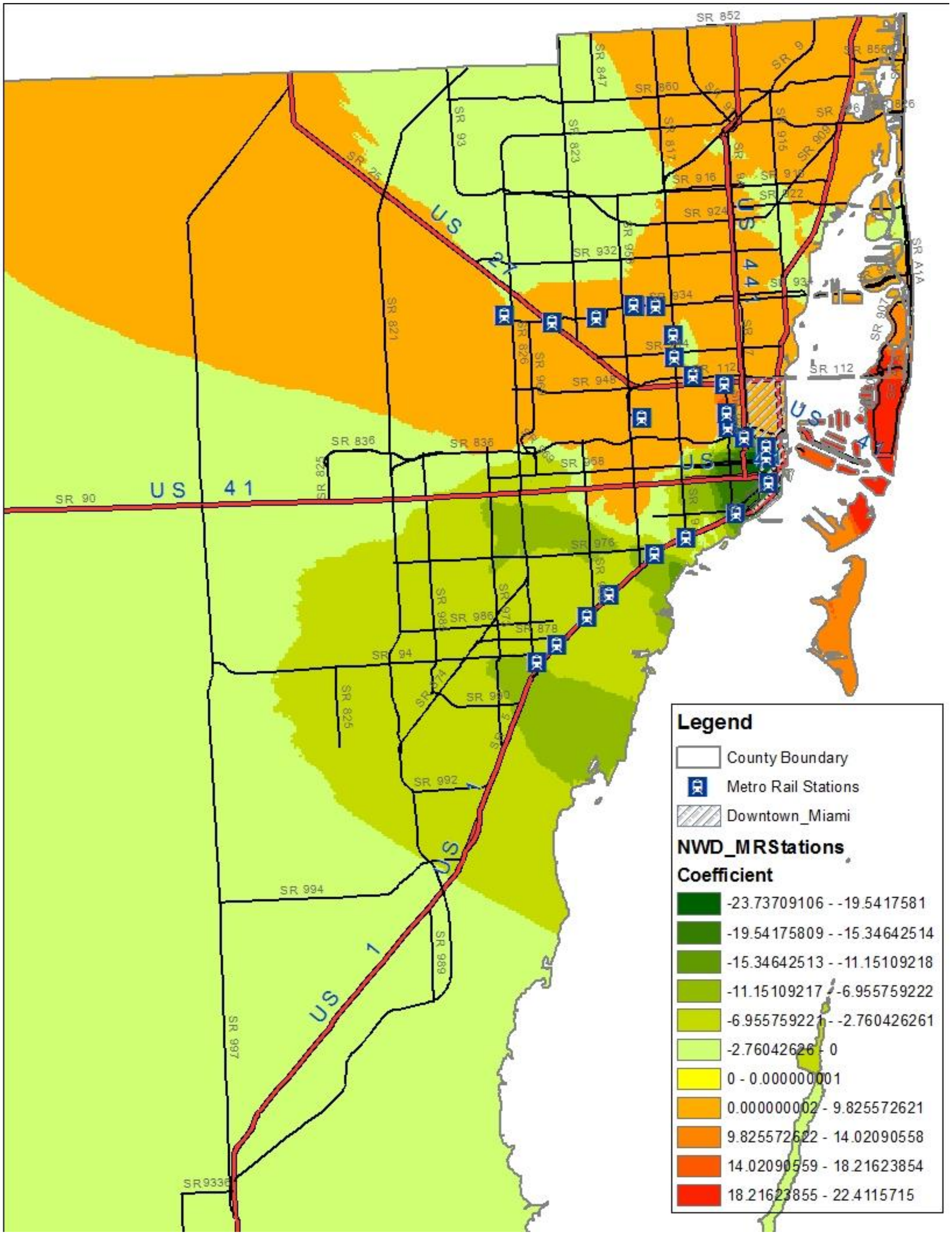

Figure 4-2. Coefficient surface of network distance to nearest metro rail station

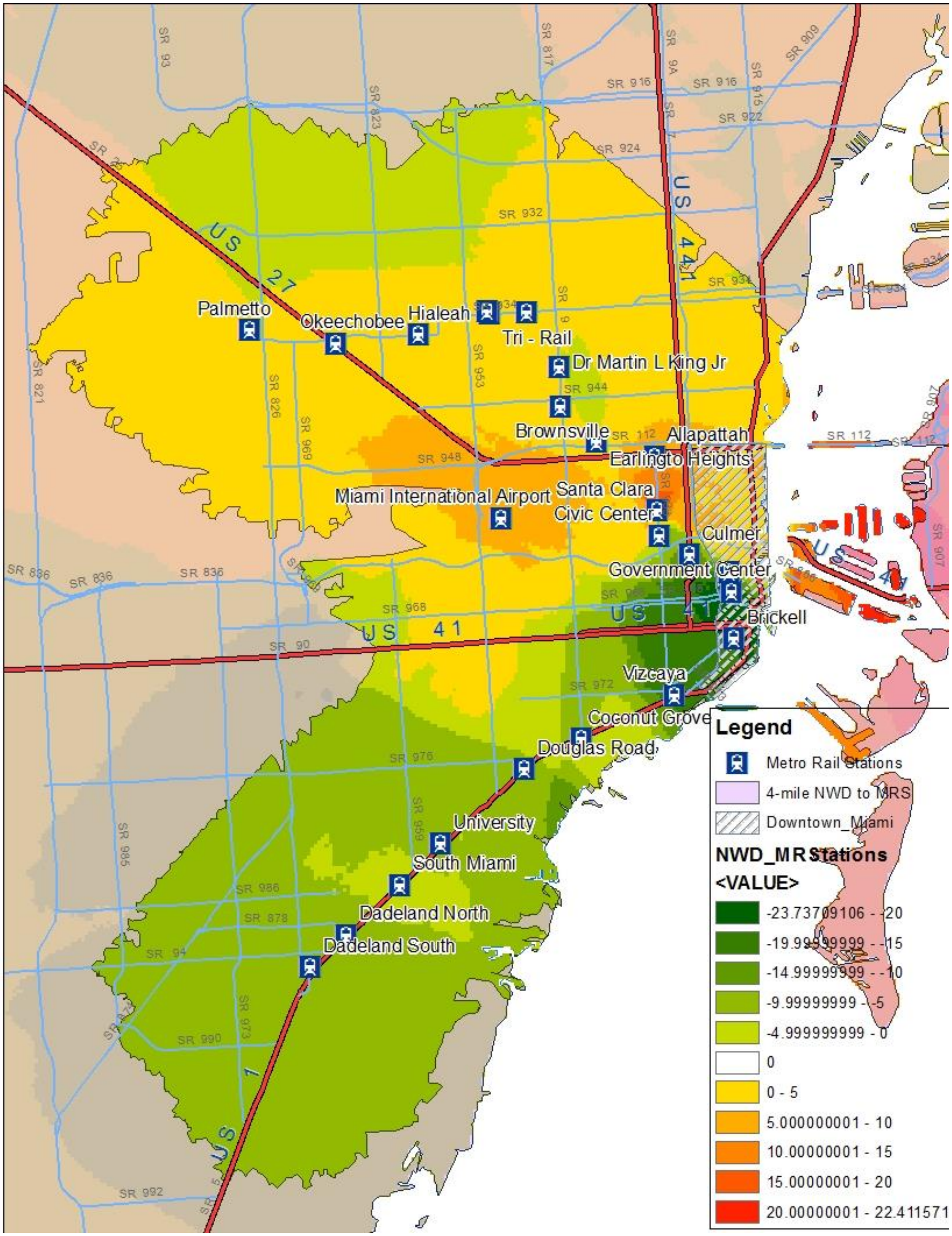

Figure 4-3. Coefficient surface of network distance to nearest metro rail station within 4 mile network distance buffer

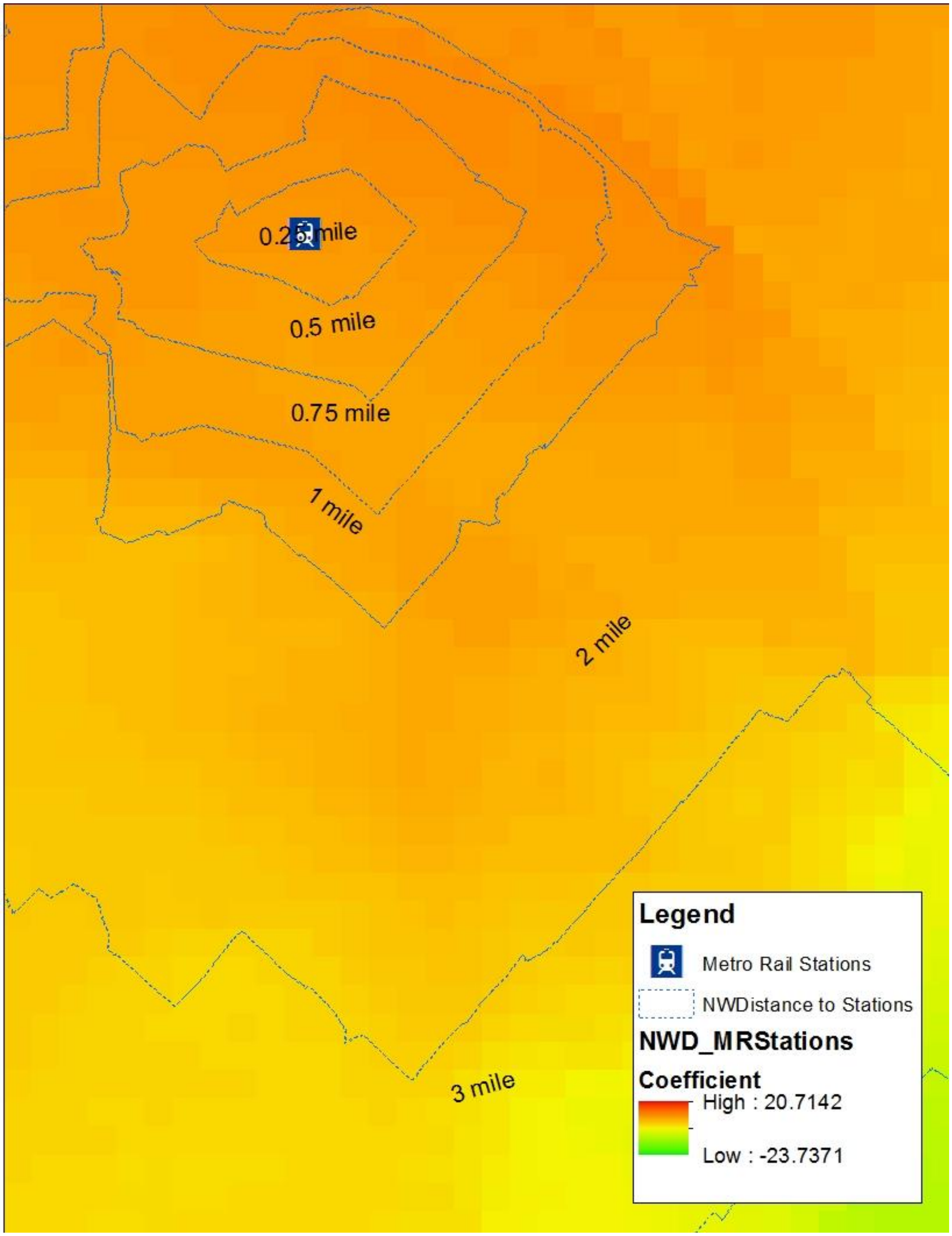

Figure 4-4. Network distance buffers around metro rail stations: ¼, ½, ¾, 1, 2, 3 and 4 miles

Table 4-3. Average coefficient of network distance to nearest metro rail station within different distance buffers

	Network Distance between Parcels and Stations (mile)					
Station Name	0 - 1/4	1/4 - 1/2	1/2 - 3/4	3/4 - 1	1 - 2	2- 4
Palmetto	1.64	1.79	1.84	1.68	1.7	1.2
Okeechobee	0.78	0.7	0.84	0.91	1.41	1.31
Hialeah	2.31	2.22	2.17	2.06	2.06	0.62
Tri - Rail	2.54	2.6	2.68	2.63	2.19	2.35
Northside	1.43	1.4	1.27	1.14	1.36	0.79
Dr Martin L King Jr	0.22	0.27	0.51	0.86	1.52	2.13
Brownsville	0.42	0.42	0.67	1.58	3.21	3.26
Earlingto Heights	1.2	1.61	2.89	4.33	5.6	5.54
Allapattah	7.36	7.4	6.8	6.08	4.11	3.52
MIA	6.33	6.39	6.35	5.94	4.26	0.98
Santa Clara	15.43	11.42	8.05	6.05	5.11	5.36
Civic Center	-1.23	-1.08	-0.34	-2.54	-4.5	-4.45
Culmer	-10.29	-7.47	-4.29	-4.35	-4.71	-18.62
Overtown/Lyric Theatre	-4.53	-4.21	0.96	3.29	6.56	17.3
Government Center	-19.68	-17.44	-17.02	-17.24	-16.33	-19.34
Brickell	-22.34	-21.53	-19.79	-17.71	-17.63	-16.79
Vizcaya	-17.67	-16.74	-15.37	-13.37	-12.59	1.92
Coconut Grove	-5.6	-4.85	-4.24	-4.5	-5.76	-3.54
Douglas Road	-7.42	-6.36	-5.98	-6.42	-4.28	-2.79
University	-5.34	-5.36	-5.41	-5.63	-6.2	-6.7
South Miami	-4.46	-4.56	-4.74	-4.93	-5.29	-6.73
Dadeland North	-5.96	-5.89	-5.76	-5.7	-6.01	-6.98
Dadeland South	-6.77	-6.81	-7.14	-7.2	-7.02	-6.4

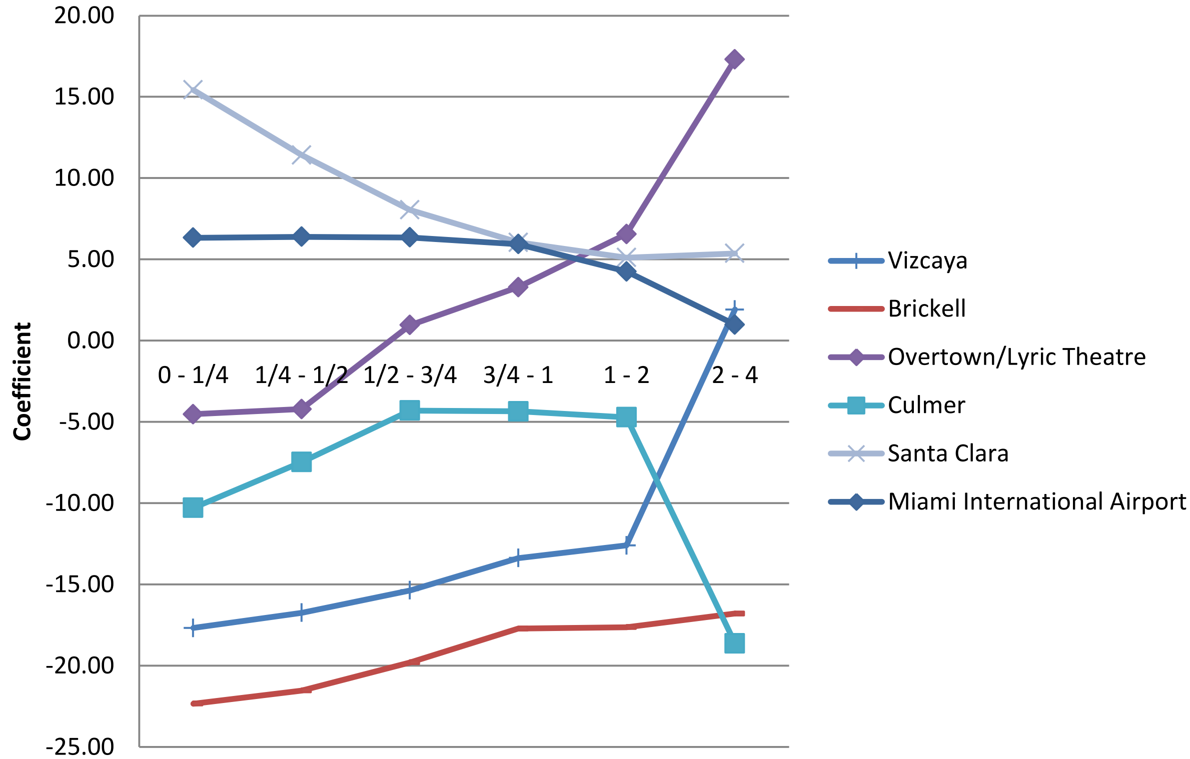

Figure 4-5. Coefficient of network distance to nearest metro rail stations fluctuated with distance between stations and commercial properties

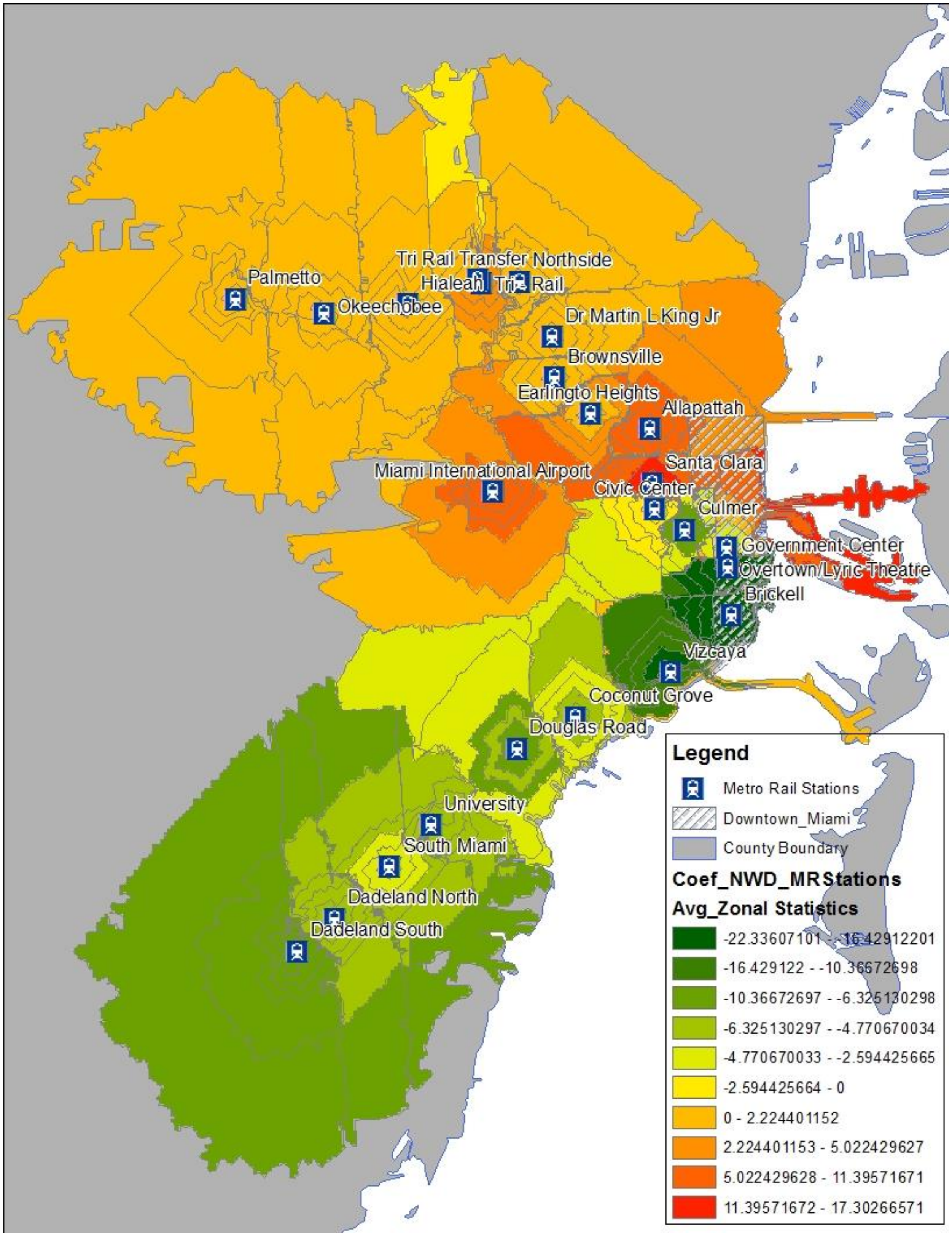

Figure 4-6 Zonal statistics of average coefficient of network distance to nearest metro rail station within different distance buffers

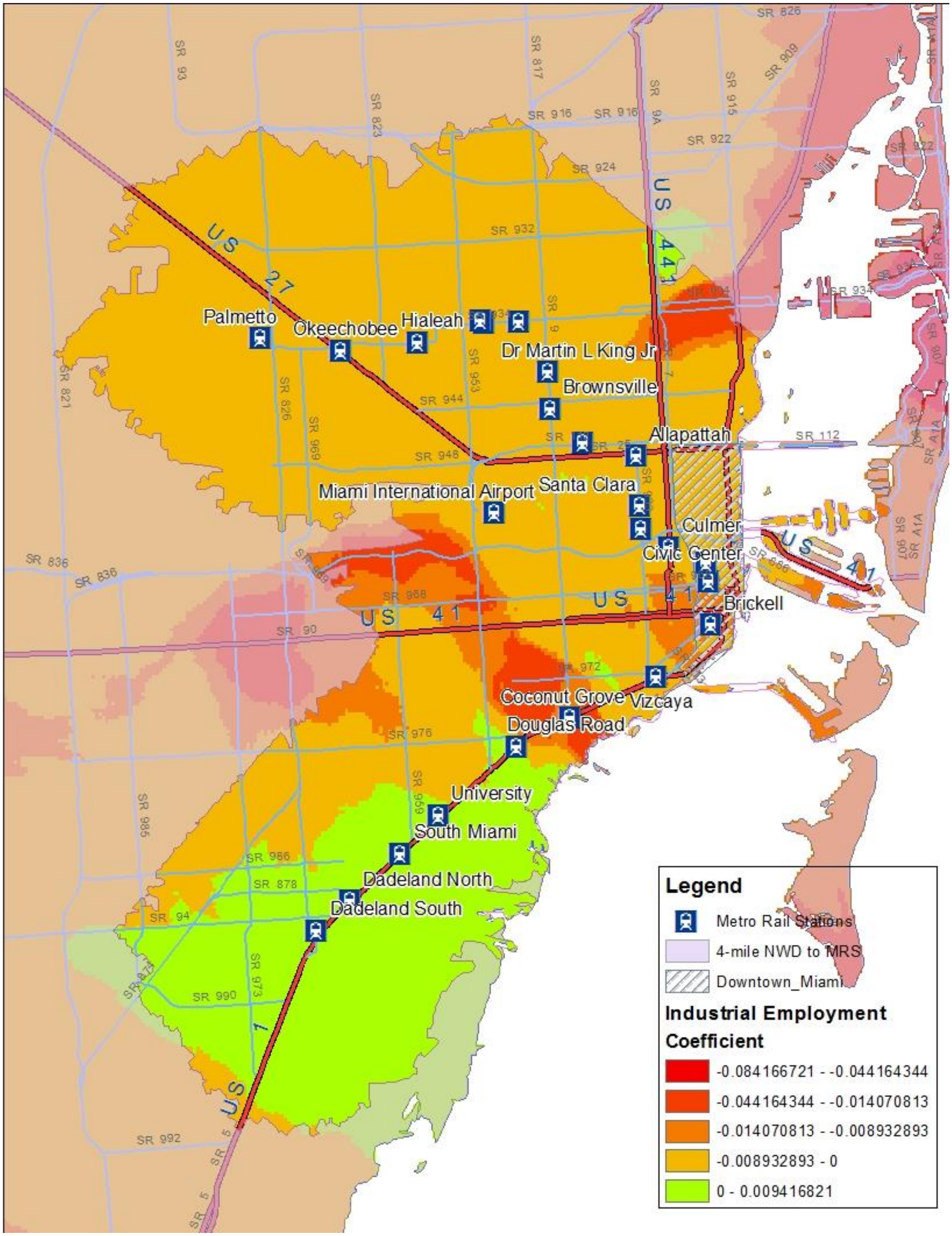

Figure 4-7. Coefficient surface of industrial employment within one mile radius

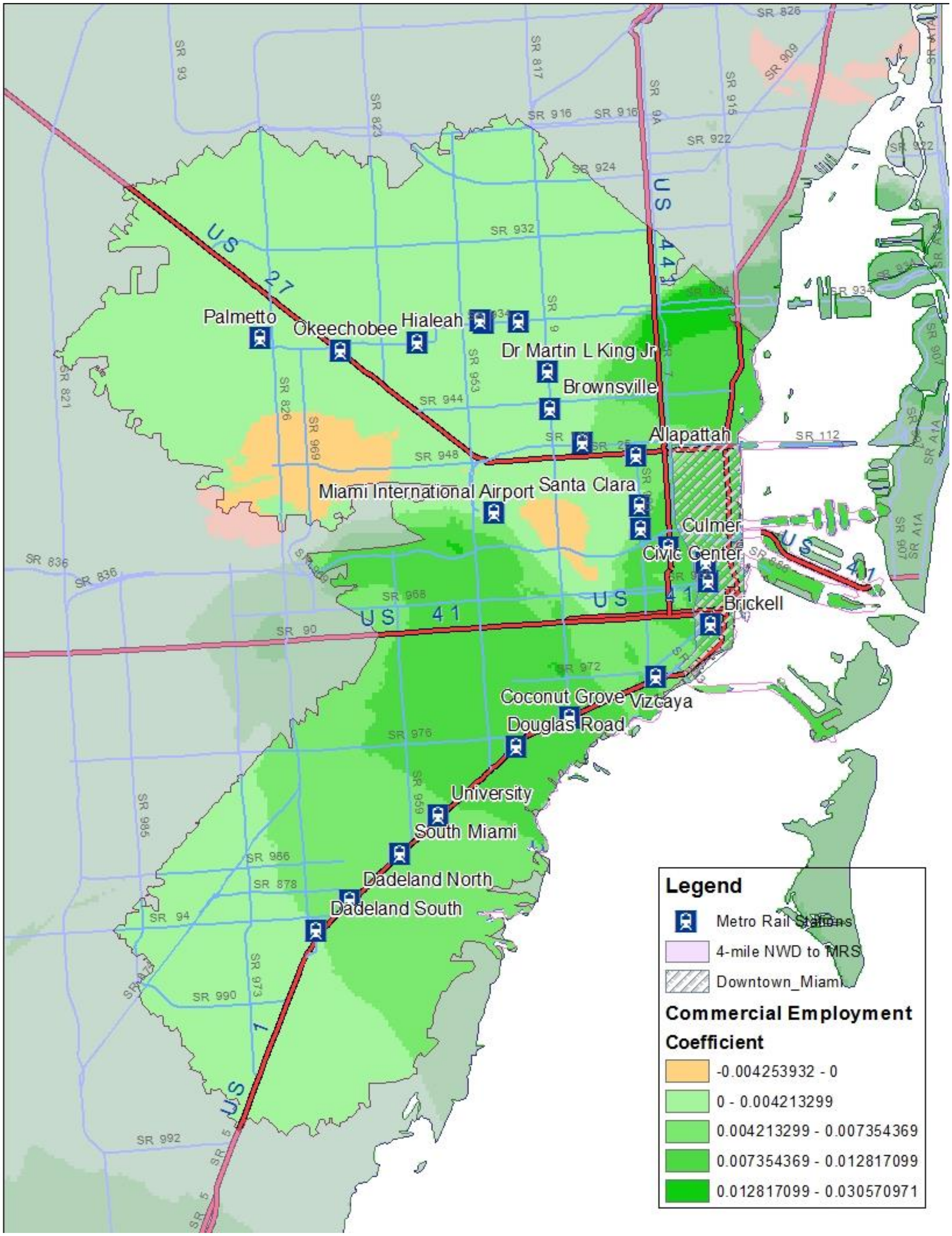

Figure 4-8. Coefficient surface of commercial employment within one mile radius

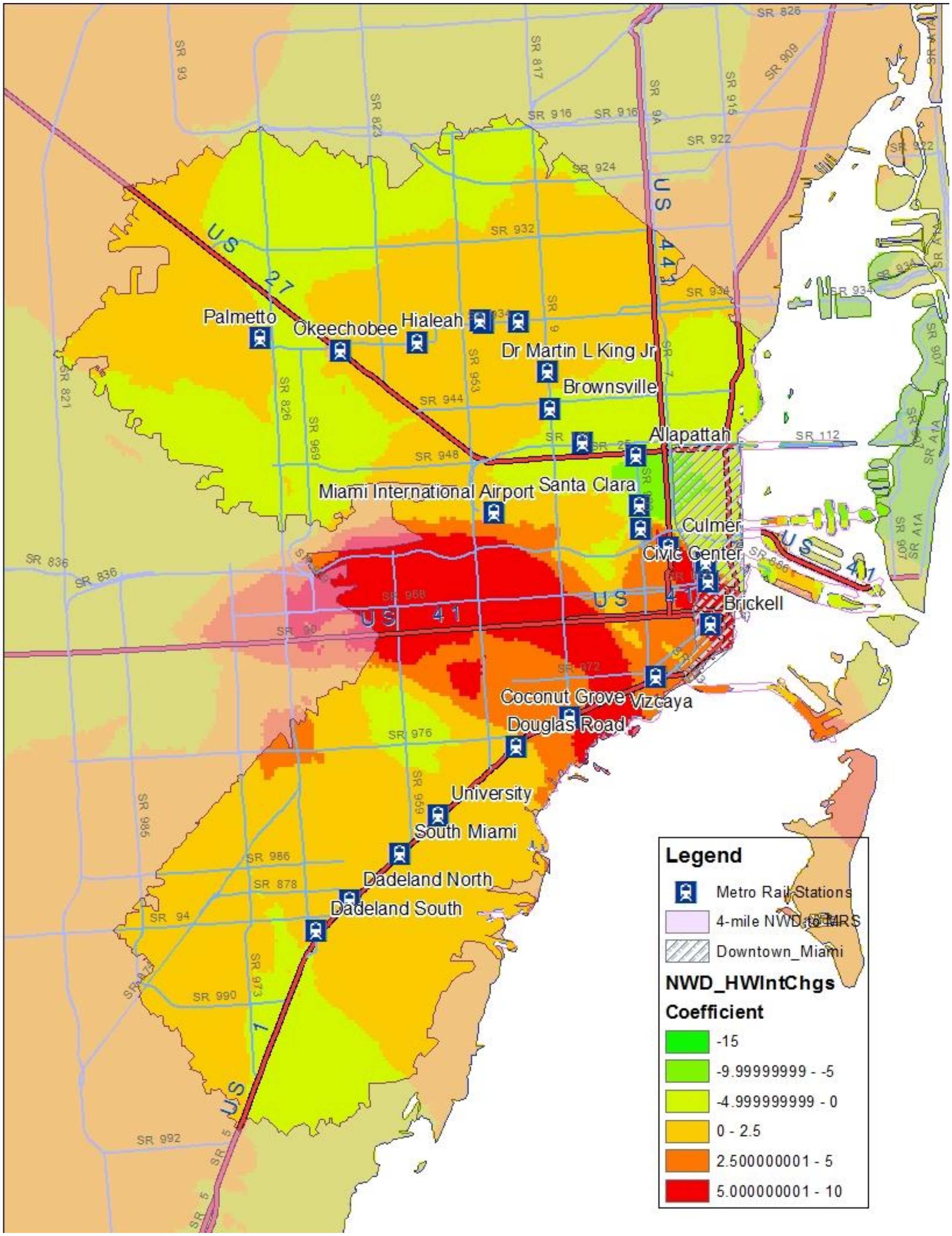

Figure 4-9. Coefficient surface of network distance to nearest highway interchanges

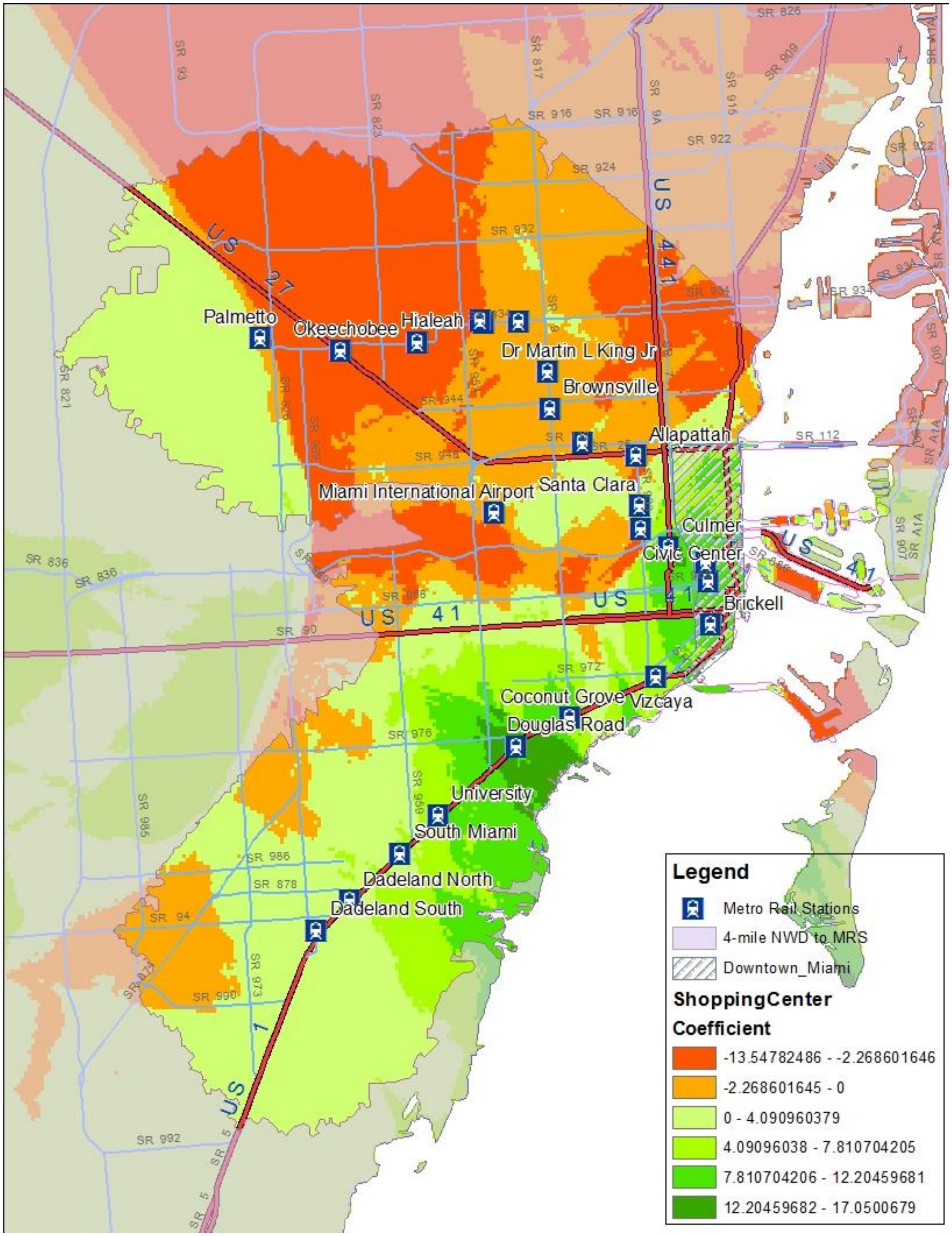

Figure 4-10. Coefficient surface of shopping center

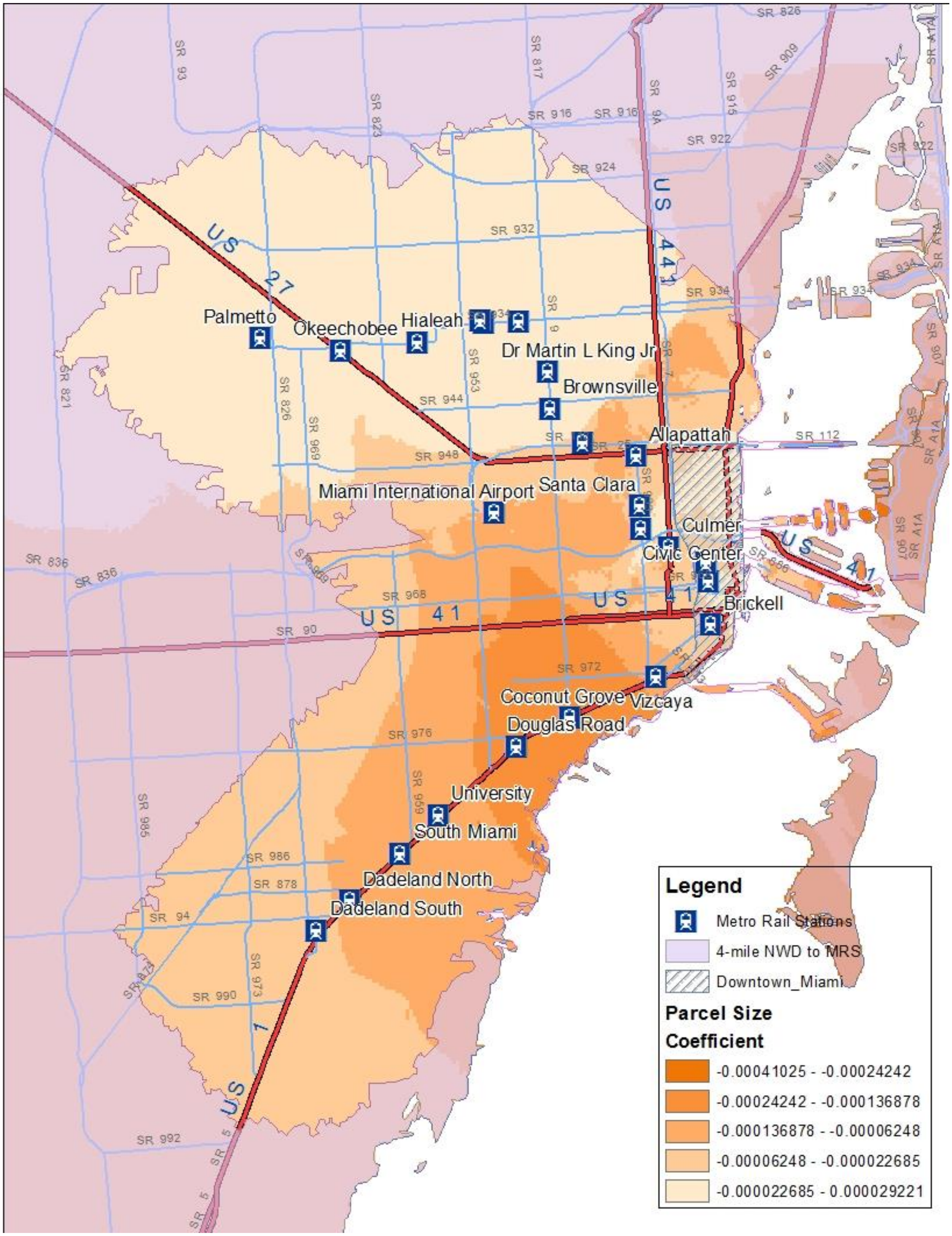

Figure 4-11. Coefficient surface of parcel size (square feet)

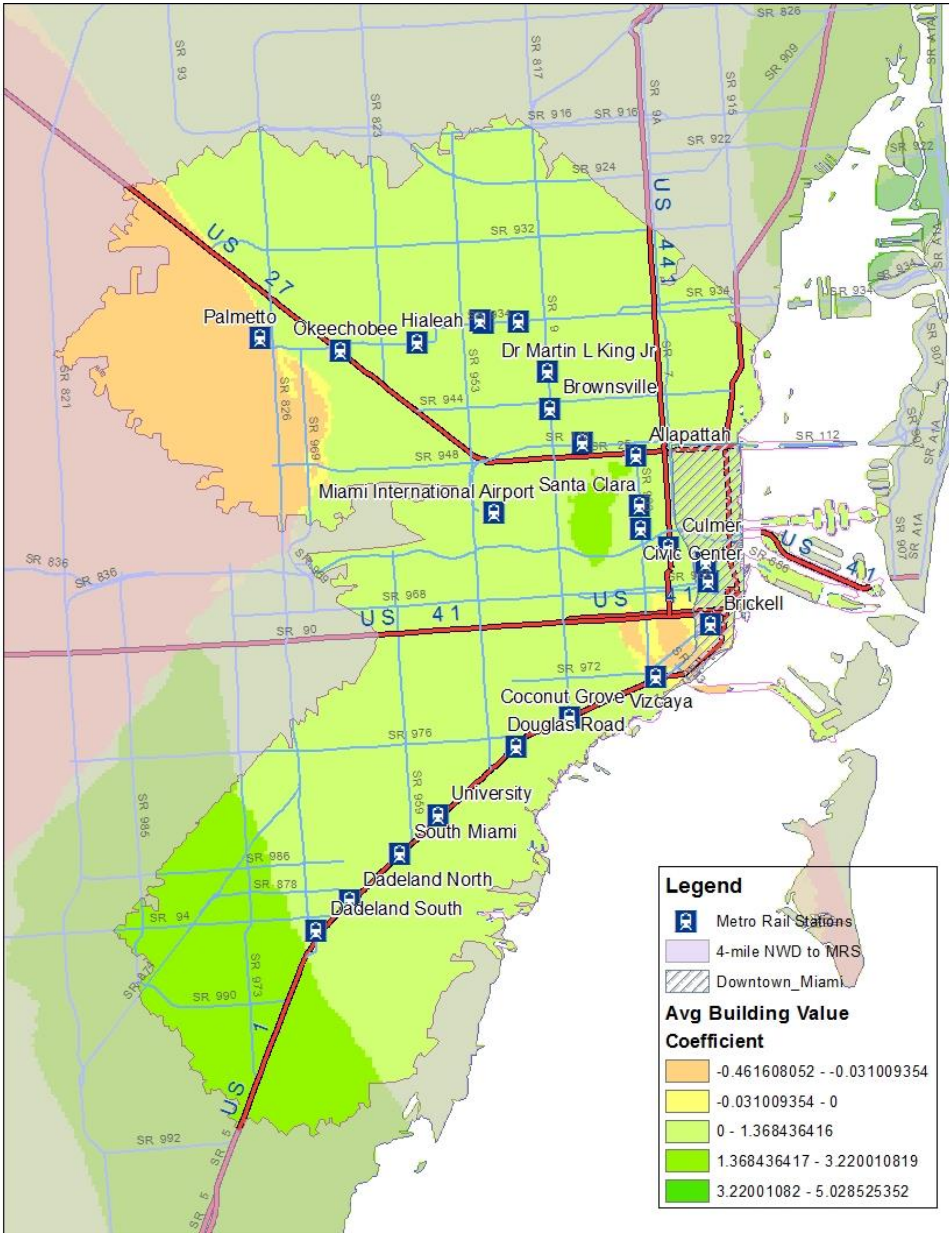

Figure 4-12. Coefficient surface of average building value within one mile radius

Exploration of Coefficient Variation

Local coefficient values also provide an opportunity of exploring the causes of spatial variation in the impact of metro rail stations on commercial property values. It would be interesting to know why some metro rail stations have positive impacts on commercial properties around them while others have negative ones, and what characteristics of metro rail stations would affect their impact on commercial property values.

The study applied zonal statistics to summarize average coefficient values and basic demographic, socioeconomic and neighborhood characteristics within a one mile network distance of every metro rail station, as shown in Table 4-4. A binary logistic regression model and two linear regression models were used to explore the relationship between characteristics of metro rail stations and their impact on commercial property values within a one mile network distance.

The binary logistic regression was implemented to test whether positive impacts from metro rail stations on commercial property values are affected by selected demographic, socioeconomic and neighborhood characteristics of metro rail stations. According to the previous GWR model, the coefficient value of the network distance represents the dollar value change in commercial property value for every one mile increase in the distance between commercial properties and metro rail stations. In this model, the average coefficient values within a one mile network distance to metro rail stations were recoded into a dummy variable. In the dummy variable the value 1 represents the average coefficient value that is negative., Negative values mean that the metro rail station has a positive impact on commercial properties locating closer to the station.; In the dummy variable the value 0 represents the average coefficient value

Table 4-4. Demographic, socioeconomic and neighborhood characteristics within one mile network distance to metro rail stations

Station Name	Avg coef	Den pop	Income (10k)	INDU_EMP	SERV_EMP	COMM_EMP	Bus Stop	Single Family	Count Intersection	Weekday Ridership
Dadeland South	-7.31	18	7.8	401	6812	6470	30	681	99	7976
Dadeland North	-6.00	14	6.2	533	3828	6063	39	1069	131	6996
South Miami	-4.85	8	6.4	881	20164	4279	82	1908	187	3799
University	-5.51	8	8.1	114	11210	1570	56	869	164	2588
Douglas Road	-6.77	12	5.9	524	11552	3912	90	2300	259	4453
Coconut Grove	-4.47	17	5.7	492	9164	2838	89	2401	177	2026
Vizcaya	-14.44	19	5.9	97	6511	659	60	2042	159	1576
Brickell	-18.68	33	5.1	1695	31317	7005	104	508	222	5600
Government Center	-21.21	32	3.2	1409	42462	8911	180	99	401	11854
Overtown/Lyric Theatre	-9.13	21	3.0	1254	36130	6798	177	140	421	2012
Culmer	-3.65	22	2.2	4585	31840	1718	189	368	332	1553
Civic Center	6.20	21	2.3	5007	24329	2559	148	666	226	6336
Santa Clara	8.75	20	2.4	5128	24911	3067	144	853	191	951
Allapattah	6.29	17	2.8	299	2880	1932	107	2297	211	2234
MIA	6.13	17	3.4	869	2744	949	20	982	136	1493
Earlingto Heights	3.95	20	2.4	662	5947	1902	110	2096	148	1869
Brownsville	0.88	11	2.9	933	4285	1282	122	2649	134	1084
Dr Martin L. King Jr.	0.75	8	2.9	606	4212	1461	101	2176	114	1559
Northside	1.64	8	3.4	1238	2388	2231	75	1596	99	1685
Tri - Rail	2.28	13	3.5	2014	2615	2494	60	2032	90	1509
Hialeah	2.14	22	2.3	732	4078	1803	80	1775	158	1792
Okeechobee	0.90	18	4.1	1846	2661	2129	51	1061	125	1502
Palmetto	1.80	16	3.9	1192	1570	3149	7	0	42	1536

that is positive., Positive values mean the metro rail station has a negative impact on commercial properties close to the station. Negative_coef is the dependent variable. Independent variables include population density, median household income, number of industrial, service and commercial employees, number of bus stops, intersections, and single family housing units within a one mile network distance of every metro rail station as well as its average weekday daily ridership in 2010.

As shown in Table 4-6, the model found that only median household income has a significant impact on whether a metro rail station would have an overall positive or negative impact on commercial property values within a one mile network distance around it. Every 10,000 dollar increase in median household income within the 1 mile network distance to a metro station would increase the probability of that metro station having a positive impact on commercial property values by 124.8%. This means that metro rail stations located in high income neighborhoods are more likely to increase commercial property values around them than those located in low income neighborhoods, which is consistent with the findings from the previous GWR model that metro rail stations have positive impacts on most of the southern parts of Miami-Dade County where household income is relatively high, while having a negative impact on most of the northern areas where household income is lower.

A linear regression model was implemented to test whether the overall impact from metro rail stations on commercial property values are affected by selected demographic, socioeconomic and neighborhood characteristics of metro rail stations. The dependent variable is the average coefficient value within a one mile network distance to metro rail stations. Independent variables include population density,

Table 4-5. Descriptive statistics of binary logistics model I

Variables	Mean/ Proportion	Std. Deviation
Dependent Variable:		
Negative average coefficient value (1 = yes, 0 = no)	47.82	-
Independent Variables:		
Population density within one mile network distance	17	7
Number of industrial employment within one mile network distance	1414	1479
Number of service employment within one mile network distance	12766	12696
Number of commercial employment within one mile network distance	3269	2256
Number of bus stops within one mile network distance	92	51
Number of single family housing units within one mile network distance	1329	840
Number of intersections within one mile network distance	184	95
Median household income (10k) within one mile network distance	4	2
Average weekday daily ridership	3217	2709

Table 4-6. Binary logistics model summary

Variables	Standardized Coefficients	Probability
Median household income (10k) within one mile network distance	1.248	0.014
Summary Statistics:		
Number of observations = 23		
-2 Log likelihood = 19.062		
Cox & Snell R Square = 0.426		
Nagelkerke R Square = 0.569		

median household income, number of industrial, service and commercial employees, number of bus stops, intersections and single family housing within a one mile network distance of every metro rail station as well as its average weekday daily ridership in 2010.

As shown in Table 4-8, the number of commercial employees, median household income and number of intersections within a one mile network distance to metro rail stations have significant impact on average coefficient values of commercial property values. Every commercial employee and street intersection added within one mile of the metro rail stations would decrease the average coefficient values of commercial property values by 0.347 and 0.408, respectively. The average coefficient value would decrease by 0.475 if the median household income within a one mile network distance to a metro rail station increases by $10,000.

Table 4-7. Descriptive statistics of linear regression model I

Variables	Mean	Std. Deviation
Dependent Variable:		
Average coefficient of network distance to metro rail stations on commercial property values within one mile network distance	-2.62	7.92
Independent Variables:		
Population density within one mile network distance	17	7
Number of industrial employment within one mile network distance	1414	1479
Number of service employment within one mile network distance	12766	12696
Number of commercial employment within one mile network distance	3269	2256
Number of bus stops within one mile network distance	92	51
Number of single family housing units within one mile network distance	1329	840
Number of intersections within one mile network distance	184	95
Median household income (10k) within one mile network distance	4	2
Average weekday daily ridership	3217	2709

Table 4-8. Linear regression model I summary

Variables	Standardized Coefficients	Probability
Number of commercial employment within one mile network distance	-0.347	0.057
Median household income within one mile network distance	-0.475	0.006
Number of intersections within one mile network distance	-0.408	0.026
Summary Statistics:		
Number of observations = 23		
Adjusted R Square = 0.596		
Std. Error of the Estimate = 5.035		
Durbin-Watson = 0.877		

Another linear regression model was implemented to test whether the overall extent of the impact from metro rail stations on commercial property values is affected by selected demographic, socioeconomic and neighborhood characteristics. The dependent variable is the absolute value of the average coefficient within a one mile network distance to metro rail stations. Independent variables include population density, median household income, number of industrial, service and commercial employment, number of bus stops, intersections and single family housing within a one mile network distance of every metro rail station as well as its average weekday daily ridership in 2010.

As shown in Table 4-10, one unit increase in population density, median household income (10k), and service employment would increase the extent of impact from the metro rail stations on commercial property values by \$0.621, \$0.399 and \$0.337 respectively. Metro rail stations located in neighborhoods with high population density, high median household income and clusters of service employment would have a greater extent of impact on commercial property values around them, both positive and negative.

Summary

The GWR model has explained a 72% variance of commercial property values in Miami-Dade County. The model explanatory power has significantly improved compared to the previous linear-linear global model, which explained 54% of the variance. The AIC index decreased from 70,794 to 67,089 when using a linear-linear GWR model instead of a linear-linear global model, indicating that the GWR model has overall better explanatory power and better fit than the global model when modeling commercial property values.

Table 4-9. Descriptive statistics of linear regression model II

Variables	Mean	Std. Deviation
Dependent Variable:		
Absolute value of average coefficient of network distance to metro rail stations on commercial property values within one mile network distance	6.25	5.40
Independent Variables:		
Population density within one mile network distance	17.17	6.73
Number of industrial employment within one mile network distance	1413.52	1478.61
Number of service employment within one mile network distance	12765.65	12696.48
Number of commercial employment within one mile network distance	3268.74	2255.92
Number of bus stops within one mile network distance	92.22	50.69
Number of single family housing units within one mile network distance	1329.04	840.27
Number of intersections within one mile network distance	183.74	94.69
Median household income (10k) within one mile network distance	4.17	1.82
Average weekday daily ridership	3216.65	2708.91

Table 4-10. Linear regression model II summary

Variables	Standardized Coefficients	Probability
Population density within one mile network distance	0.621	0.001
Median household income within one mile network distance	0.399	0.004
Number of service employment within one mile network distance	0.337	0.037
Summary Statistics:		
Number of observations = 23		
Adjusted R Square = 0.698		
Std. Error of the Estimate = 2.966		
Durbin-Watson = 1.597		

The GWR model also revealed that the impact of metro rail stations on commercial property values varies significantly over space. First, such impacts are different in the northern part of Miami-Dade County than in the southern part. Second, stations near the midpoint of the Miami metro rail have the greatest impact on commercial property values; the extent of impact decreases when moving from downtown to north and south ends of the rail. Moreover, the extents of impact from the metro rail stations on commercial properties also change by the distance between them. The change patterns vary by stations. Additionally, one station could have a different impact on commercial properties situated at the same distance but in a different direction.

Metro rail stations located in high income neighborhoods are more likely to increase commercial property values around it than those located in low income neighborhoods. Within a one mile network distance to metro rail stations, an increase in the number of commercial employers, median household income and number of intersections would decrease the average coefficient values of network distance to metro rail stations on commercial property values. When the direction of impact is not considered, metro rail stations located in the neighborhood with high population density, high median household income and a cluster of service employment would have a greater extent of impact on commercial property values around them.

CHAPTER 5
DISCUSSION

Many studies have been done on transit facilities' value capture trying to find correlation between property values and distance from a transit stop following the installation of rail transit improvements (Jeffery, Smith & Gihring, 2006). However, no agreement has been reached concerning this subject. Some studies found a positive impact from rail transit systems on property values while others found negative ones. Moreover, the literature also shows that rail transit systems' impact on property values vary by types of transit system and types of joint development. Additionally, many other factors, such as the size of the city, population, and its layout, also play roles in the relationship between accessibility to rail transit system and property values.

Therefore, there is no general "yes or no" answer to the question, "Does accessibility to rail transit increase property values?" Neither is there a certain answer to whether a public-private partnership based on this potential property value increment will work or not. When trying to find fiscal support for transit systems from private individuals or organizations, it is important for planners to do local analyses in their state or cities to examine the value capture of rail transit systems, which is a precondition on which public-private partnerships could be built.

The Miami metro rail system is the only heavy rail system operating in the state of Florida. This thesis, which examines its impact on commercial property values, has affirmed that heavy rail transit system has a significant impact on commercial property values in Miami-Dade County. Results from the OLS model shows that, countywide, locating one mile closer to metro rail stations is associated with decreasing commercial property value by $1.91. However, the GWR model has revealed that, locally, there are up to $22 property value premiums for siting within a one mile network distance to metro rail stations in the southern part of Miami-Dade County. With a mutual recognition of this property value increment, public-private partnerships between the rail transit agency and commercial developers could be built, where businesses enjoy good transportation accessibility, high population movement while transit facilities get financial support and secure ridership. And people get to ride transit facilities at lower cost. The analysis of the Miami metro rail provides reference for other cities in Florida when considering public-private partnerships to help build and fund rail transit systems in the future.

Having stated the claim of property value increments related to accessibility to rail transit systems, there are questions to be answered when building this public-private partnership in a real-world setting. First of all, despite the issue of land acquisition, where should transit-joint commercial developments be built? If the impact from the metro rail system on commercial property values is constant over space, the value capture power are the same in all metro stations, whether in the north end, south end or midpoint of the rail. And that is the assumption of global models used in most of the previous studies.

However, if the impact varies by geographic location (one station has greater value capture power than the others, or one station has a positive impact while the other has a negative impact on commercial property values), previous assumptions would cause severe problems. Commercial joint-developments may be built near stations that are not associated with increasing commercial property values, or are even associated with decreasing property values. Those commercial developments may not gain the benefit they expected by being located near those stations. Several studies have proven that there is spatial nonstationarity existing in the analysis of residential property values (Du and Mulley 2006; Farber and Yates 2006; Pa´ez 2005; Bitter et al. 2007). However, no study has been done to address the spatial nonstationarity issue in the relationship between accessibility to rail transit systems and commercial property values. The thesis applied the GWR model and proved that impact of accessibility to metro rail station on commercial property values vary significantly over space. First, accessibility to the metro rail station in the northern part of Miami-Dade County decreases property values around them while those in the southern part increases property values. Second, stations near the midpoint of the Miami metro rail have the greatest extent of impact on commercial property values; the extent of impact decreases when moving from downtown to north and south ends of the rail. Moreover, the impact from the Metro rail stations on commercial properties also changes by the distance between them. The change patterns vary by stations. Additionally, one station could have a different impact on commercial properties situated at the same distance but in a different direction to it. Therefore, it is better to examine the impact of rail transit on commercial property values locally instead of globally, for the purpose of building commercial developments in places that could take advantage of the rail transit's value capture power.

Having confirmed that there is spatial nonstationarity in this relationship, the GWR analysis in this thesis also provided a coefficient surface from which metro stations with considerable potential for value capture could be chosen for transit-joint commercial developments. The amount of potential increment is also important. It's hard to persuade private developers to enter into a public-private partnership if there is only a small benefit they could gain from installation of a transit system. The GWR analysis indicated that when all else is equal, the three best candidates in this case are the Brickell, Government Center and Vizcaya Stations. Potential increments in property values could be as high as $22 per square feet for every one mile closer to the metro station. Moreover, Brickell and Government Center Stations are more ideal candidates than the Vizcaya Station because there are more vacant commercial parcels within a one-mile network distance to them, according to Figure-6.

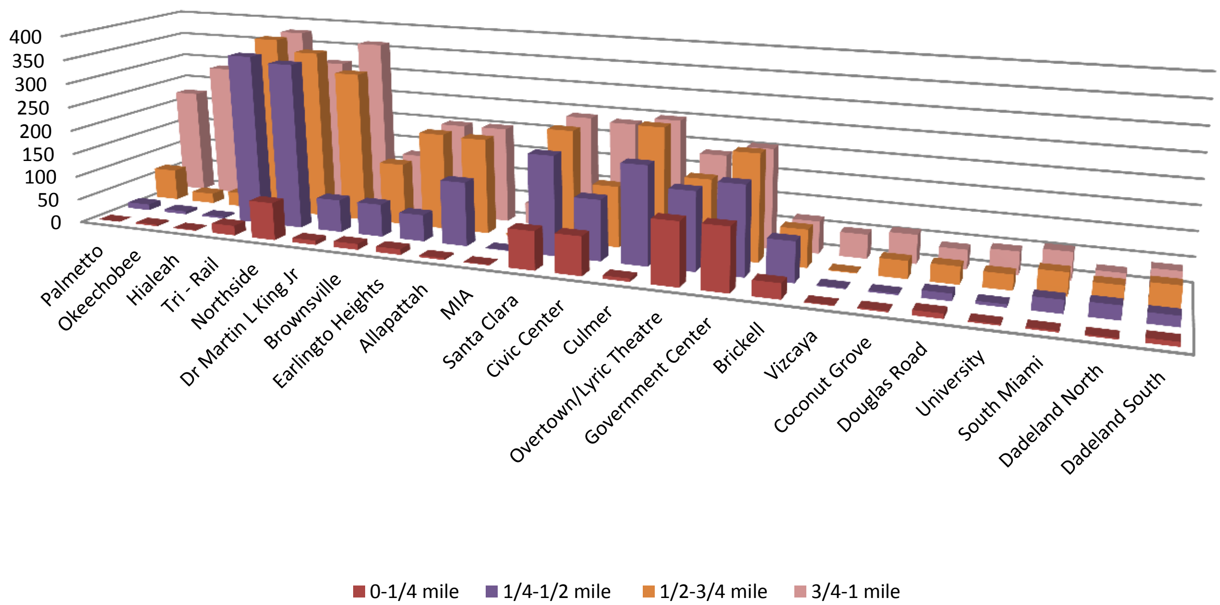

Figure 5-1. Vacant commercial parcels within one-mile network distance to metro rail stations (acres)

Figure 5-1 also illustrated that there are more vacant commercial parcels near stations in the northern part of Miami-Dade County, most of which are associated with decreasing commercial property values and are considered not suitable for commercial joint-developments. However, transit-joint developments have the potential to be more than just financial deal-making (Cervero, R., Hall, P., & Landis, J. 1990). Although private interests usually make financial contributions to transit development based on recognition that accessibility to transit service has enhanced the value or development potential of their properties, transit-joint developments could also become an instrument incorporated with other planning strategies to achieve lager transportation and land use objectives, such as encouraging non-automobile travel, stimulating redevelopment, accelerating land use conversion and creating compact, transit-oriented communities.

Therefore, incentives such as density bonus or favorable rates should be given to business owners if commercial development has to be encouraged in an area where construction of rail transit is associated with decreasing property values. Only by recognizing the spatial variation of impact from metro rail systems on commercial property values could flexible planning strategies be set up in a way to fully utilize the value capture potential of the transit system, This would also help commercial development overcome possible negative impacts from transit systems when there are larger planning objectives to be achieved.

Recognizing the spatial variation in impact of metro stations leads to an inquiry about possible reasons for such variation. Why do some metro rail stations have positive impacts on commercial properties around them while others have negative ones? Why the extent of impact is greater in one station than that it is in another? What demographic, transportation or socioeconomic characteristics of areas adjacent to metro stations could have contributed to the variation of their impact on commercial property values? One method to find out the answers is to summarize and compare characteristics of stations.

Another way would be to run regression models. The thesis did both and found that median household income has a significant impact on whether a metro rail station would have an overall positive or negative impact on commercial property values within a one mile network distance around it. Every 10,000 dollars increase in median household income within a 1 mile network distance to a metro station would increase the probability of that metro station having a positive impact on commercial property values by 124.8%. Population density, median household income (10k) and service employment have significant effects on the extent of the impact from metro stations on commercial property values.

A one unit increase in population density, median household income (10k) and service employment would increase the extent of impact from metro rail stations on commercial property values by \$0.621, \$0.399 and \$0.337 respectively. Therefore, accessibility to Miami metro rail is most likely to have the greatest positive impact on commercial property values when stations are located in an area with high median household income, high population density and clusters of service employees. The result also provided a reference for locating rail transit stations or finding area with good transit value capture potentials in Miami-Dade County or other places in Florida.

After choosing the location, the next question would be what type of commercial development should be built close to a particular metro station? Several previous studies using only global models indicated types of commercial development matters, meaning metro stations may have different impacts on retail stores and shopping malls. But none of these previous studies show how the difference of impact varies by geographic locations, or by stations. Even a global model shows that on average, countywide, one type of commercial development has greater potential for property value increment than another. It is possible that such superior potential is not constant over space, that is to say, a type of commercial development may have greater potential in some areas while having less potential in another when compared to other types of commercial development.

This thesis tackled the problem by using GWR to produce coefficient surface for the type of commercial development. A shopping center has significant impact on commercial property values; it has positive impact on properties around most of the southern stations while having a negative impact on those near northern stations. If a transit-joint development project involving a shopping center was built in Miami-Dade County, it is recommended it be built close to stations in the south, especially near the Douglas Road Station, to fully utilize the potential of property value increment. When all else is equal, building a shopping center near the Douglas Road Station could add up to a $17 premium on property values rather than building other types of commercial development. On the contrary, the shopping center is associated with decreasing commercial property values around stations in north Miami Therefore, in these areas it is better to build other types of commercial projects.

Considering the great variations in the impact of Miami metro rail stations on commercial property values, applying a global model to investigate such fairly complicated relationships is not appropriate and could cause serious missed estimations. GWR provides the ability to capture spatial variance in relationships between commercial property values and attributes affecting it. Global models imply that accessibility to metro rails has a negative impact on commercial property values, and the extent of such impact is relatively small (less than $2 per square feet for every one mile closer to metro rail stations).

However, the GWR model has revealed that the impact of metro rail stations on commercial property values varies across Miami-Dade County. They have a positive impact on most commercial properties in the south area while they have a negative impact on those in the north. Moreover, premiums of proximity to metro rail stations near some stations are much higher than the average premiums of the entire study area. For example, locating one mile closer to the Brickell Station would increase commercial property values by $22 per square feet. Premiums on proximity to Vizcaya Government Center stations are about $17 and $19 per square feet, respectively.

GWR results have revealed that the Miami metro rail brought considerable benefit to commercial properties in some areas, which would have been hidden if we only looked at results from a global model. By examining this relationship locally, the study found that the impact of metro rail stations on commercial property values is much greater than what is indicated in global models. Instead of providing a general answer to the question whether the metro rail is good for commercial properties or not, the GWR model gives details about where metro rail stations are associated with increasing or decreasing commercial property values and how the extent of such impacts vary by geographic locations and neighborhood characteristics. Those details are useful for building a public-private partnership in which metro rail agencies and commercial property owners could benefit from each other.

For example, because locating in an area within a one mile radius of the Vizcaya, Brickell and Government Center Stations are highly beneficial to commercial properties (premium of $13 to $22 per square feet), commercial TJD projects could be set up in a way that commercial property owners provide financial assistance with facility constructions or join a revenue-sharing program as a return for the benefit they receive from the metro rail.

On the other hand, since Santa Clara station is associated with decreasing commercial property values around it, it is not recommended for commercial joint-development to locate in this area if the primary objective is to take advantage of transit value capture. For areas near stations that are associated with decreasing commercial property values, when there are greater planning goals (e.g. encourage transit-oriented development, create employment opportunities) other than fiscal reasons, incentives such as density bonus or favorable rates should be given to business owners to help them overcome possible obstacles and have successful public-private partnerships. Alternatively, other types of joint-development (e.g. residential development) should be considered if further research was done to show that they could benefit more than commercial development from locating closer to metro stations.

However, all of these were made possible through the recognition and analysis of spatial variation in relationship between accessibility to rail transit and property values. Without analyzing this relationship locally rather than globally, the possibility for commercial development to utilize the potential of value capture of the Miami metro rail would have been hidden or the premium would have been incorrectly estimated. Efforts given by both transit agencies and private participants could be in vain due to a choice of the wrong place or types of commercial development for construction of transit-joint development. Policies, incentives and other planning strategies could not be made to adapt to the spatially various impacts from metro rail on commercial property values.

To summarize, GWR has several advantages over OLS. Studying the impact of accessibility to rail transit on commercial property values reveals the possibility of commercial transit-joint development, selection of suitable locations for full utilization of transit value capture, and development of flexible planning strategies to adapt to spatial variations in impact from metro rails on commercial development.

CHAPTER 6
CONCLUSION

In order to address the questions raised by business owners, developers and policy makers about whether the metro rail system could benefit from commercial development or not, this thesis has conducted statistical analyses to investigate the relationship between accessibility to metro rail stations and commercial property values.

First, empirical studies were reviewed to summarize trends and findings in previous literature. No agreement has been reached concerning the metro rail system's impact on commercial property values. The issue of spatially nonstationarity in the relationship between accessibility to rail transit stations and commercial property values has not been well explored.

Second, two ordinary least square models and one geographically weighted regression model were developed to test the research hypothesis. Results from two OLS models have affirmed the hypothesis that accessibility to a metro rail station has significant impact on commercial property values. Locations that move every one mile closer to metro rail stations could decrease commercial property value by $1.91. GWR has proved the other hypothesis that there is spatially nonstationarity in the relationship between accessibility to metro rail stations and commercial property values. The impact of metro rail stations on commercial property values has shown significant spatial variance in direction and extent. Opportunities for commercial transit-joint development would have been hidden if the issue of spatial nonstationarity had not been addressed.

Additionally, the study utilized local coefficient values from the GWR model to explore reasons for the spatial variations in the impact from metro rail stations on commercial property values, and characteristics of metro rail stations and their surrounding areas that affect this variation. It is recommended that TJD involving commercial development be implemented in areas with high median household income, high density and close to service employment centers in order to maximize the metro rail system's value capture effect on commercial property values.

Comparing results from OLS and GWR models, GWR proved to be a more suitable model than OLS in respect to explanatory power, goodness of fit and ability to assist better decision-making processes concerning rail transit and commercial joint development according to geographic location.

CHAPTER 7
FUTURE RESEARCH

The study has several limitations and a couple of things could be done to improve it in future research. First, the study only uses physical accessibility, network distance from commercial properties to metro rail stations, to measure accessibility to the rail transit system. More sophisticated measurements (e.g. gravity-based accessibility, time-space measurement, utility-based measurement, etc.) should be included in future research to address accessibility to rail transit systems in different perspectives.

Second, the issue of spatial nonstationarity should not be ignored in future research concerning the relationship between rail transit system and property values. Business owners, developers and policy makers should consider impacts from rail transit systems in a more local and disaggregated perspective, because opportunities for win-win situations through public and private partnerships could have been missed if spatially constant relationships across a large geographic area was assumed.

Last but not least, future research needs to concentrate on variations in model goodness of fit over space. Key explanatory variables could have been missed in areas with low model goodness of fit. Using larger relational databases and applying data mining tools would be helpful for detecting unique variables that may not be significant over large study areas but might have significant contributions to the model’s goodness of fit in local areas. A model utilizing different variables in different geographic locations could be developed to maximize goodness of fit and to minimize local residuals across the entire study area and to establish a more comprehensive understanding of the relationship between rail transit system and commercial development over space.

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BIOGRAPHICAL SKETCH

Yingfei Huang received her bachelor's degree of Engineering in Transportation Management at Wuhan University of Technology in China. In December 2014, she will graduate with a Master of Urban and Regional Planning degree, with a focus in transportation and land use planning.

During the past two years, Yingfei Huang has conducted research in variety of planning contexts including transportation, land use, and sustainable development. While studying in University of Florida, she participated in urban planning internship with City of Gainesville Regional Transit System, a local transit agency dedicated to provide public transit service in Gainesville, Florida. These experiences provided her with valuable knowledge and insight into the field of urban planning. Her research interests include transportation modeling, transportation and land use interaction and geospatial analysis.