SPATIALLY VARYING IMPACT OF URBAN RAILWAY ON RESIDENTIAL PROPERTY VALUES IN BANGKOK

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ABSTRACT

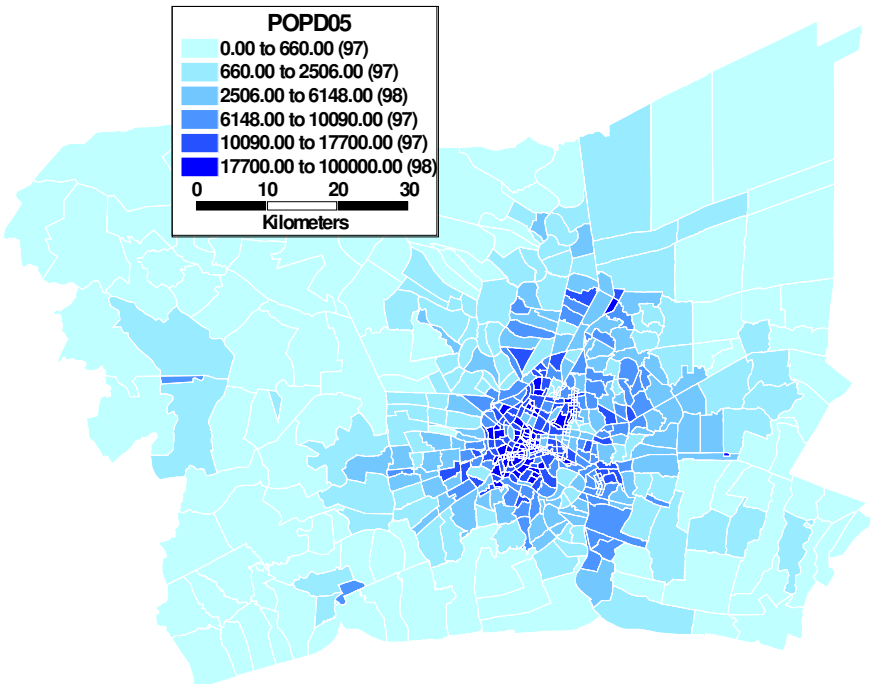
It is well recognized that urban rail transit brings a large benefit to adjacent areas; however, its spatial influence is still questionable, especially in cities with relatively little urban railway experience. The purposes of this study are to examine the impact of an urban railway on land development by investigating the land value and building stock; and to determine the variation of the impact through a spatial hedonic study. The case study considers an area along a corridor of the BTS railway line. This was Bangkok's first urban rail transit; it has been in service for nearly ten years. We examined the impact of the railway on the area development and found that there has been a rapid increase in the number of buildings and floor space. We show that this is mainly caused by the urban railway by a comparison with a parallel road corridor that the railway service does not reach. As a result, the land values along the railway corridor have been increasing compared to other places in the city. The hedonic study of residential property reveals the influencing factors such as age and station proximity. A spatial hedonic model in the geographically weighted regression framework shows the spatial variation of the coefficients. Station proximity has a strong influence on the property values when the access to the station is poor. Our results provide useful information for improving railway services such as station access or feeder services.

INTRODUCTION

Since 1960, the Bangkok Metropolitan Area of Thailand has undergone rapid urbanization. In 2005, the region contained 16.8% of the country's population and produced 44.2% of the GDP. At present, the city is extremely busy with almost all kinds of activities being carried out. The residential and employment locations are largely concentrated in the inner core, as

shown in Figure 1a and 1b. This urban structure inevitably generates a huge travel demand, mostly for long-distance trips by private vehicles.

(a) Population Density Unit: number/km^2



(b) Employment Density

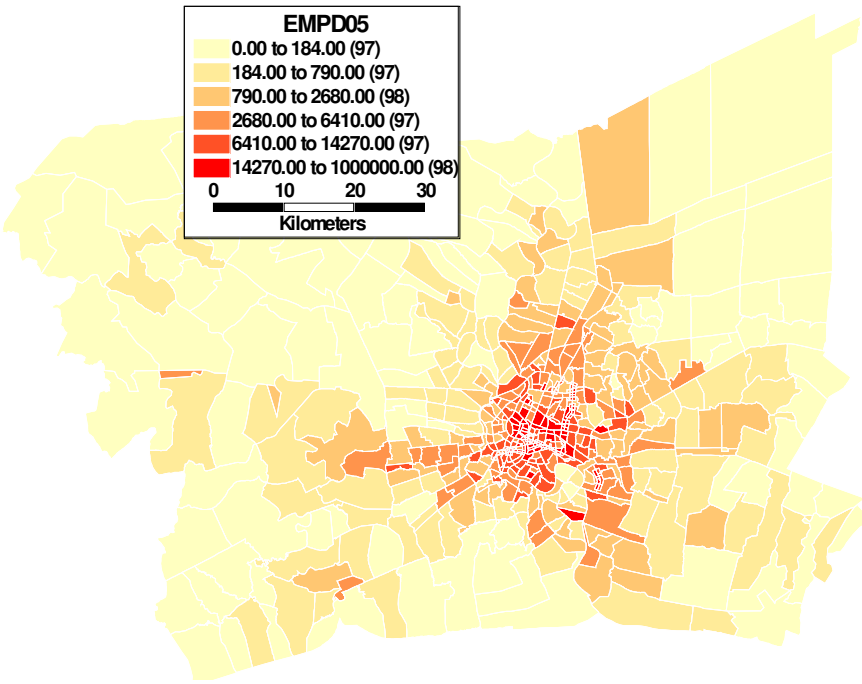


Figure 1 Population and Employment Concentrations

Transportation in Bangkok is presently based on roads. In 2005, the private modal share was 53% and the public modal share was 44%. This is because travel by private cars is far superior to travel on crowded buses running in heavily congested traffic. The present 404 bus routes are not enough to accommodate the travel demand, especially to/from suburban areas. Bangkok has relatively little rail transit history, although the State Railway of Thailand (SRT) intercity lines have provided services for travel to/from suburban areas. Recently, urban rail transit has been introduced. In 1999, BTS Corporation began operating a 23-km elevated urban railway with initially two lines. In 2004, the Mass Rapid Transit (MRT) Authority opened a 20-km urban subway line. There are five transfer stations in the BTS, MRT, and SRT system: Asoke, Mo Chit, Siam Square, Hualumphong, and Bangsue. Travel by railway in Bangkok has become attractive because of its safe, punctual, and convenient service.

Because of its popularity, the urban railway has a large influence on its surrounding area, especially around the stations. Since the BTS railway in Bangkok opened, land prices along the corridor have increased remarkably especially at the transfer stations (Vichiensan et al., 2007). It is claimed that the transit-accessibility premium for property values is approximately $10 for every meter closer to the station (Chalermpong, 2007). The benefit provided by railway service is also reflected by the land speculation along the recently announced future railway lines such as in the Rattanathibet and Bang Yai areas along the subway line extension to the north. Developers have been expecting a tremendous increase in land value after the project is completed. Similarly, in Hong Kong, there were positive price expectation effects well before the completion of the tunnel (Yiu and Wong, 2005). The expectation effects allow the government to finance infrastructure projects by selling land in the affected districts in advance.

The objectives of this study are to examine the impact of an urban railway on land development using actual data; and to determine the spatial variation of the impact via a spatial hedonic study. The case study considers an area along a corridor of the BTS railway line. This was the first urban rail transit in Bangkok; it has been in service for nearly ten years. The rest of the paper is organized as follows. We first describe the data used. The following section examines the impact of urban rail transit by considering the changes in land value and building stock. Then the hedonic price models are presented; they determine the factors influencing property values. The coefficient variation within the study area is also discussed. The model parameters are estimated using the sample data. Finally, the paper concludes with the implications for transit development, e.g., station access improvement.

Data

This study uses information and data from various sources. The information on land values is obtained from the land-value reports assessing values for four-year intervals, published by the Department of Land for the period from 1992 to 2003 and by the Treasury Department for the period from 2004 to 2011. Although the assessed land value is often lower than the market-transaction price, it is used in this study because the market-transaction price data are not consistent and reliable in Thailand.

A field survey was conducted to obtain detailed information for the residential properties. We sampled 180 residential properties in the area along the corridor of the BTS Sukhumvit line, as shown in Figure 2.

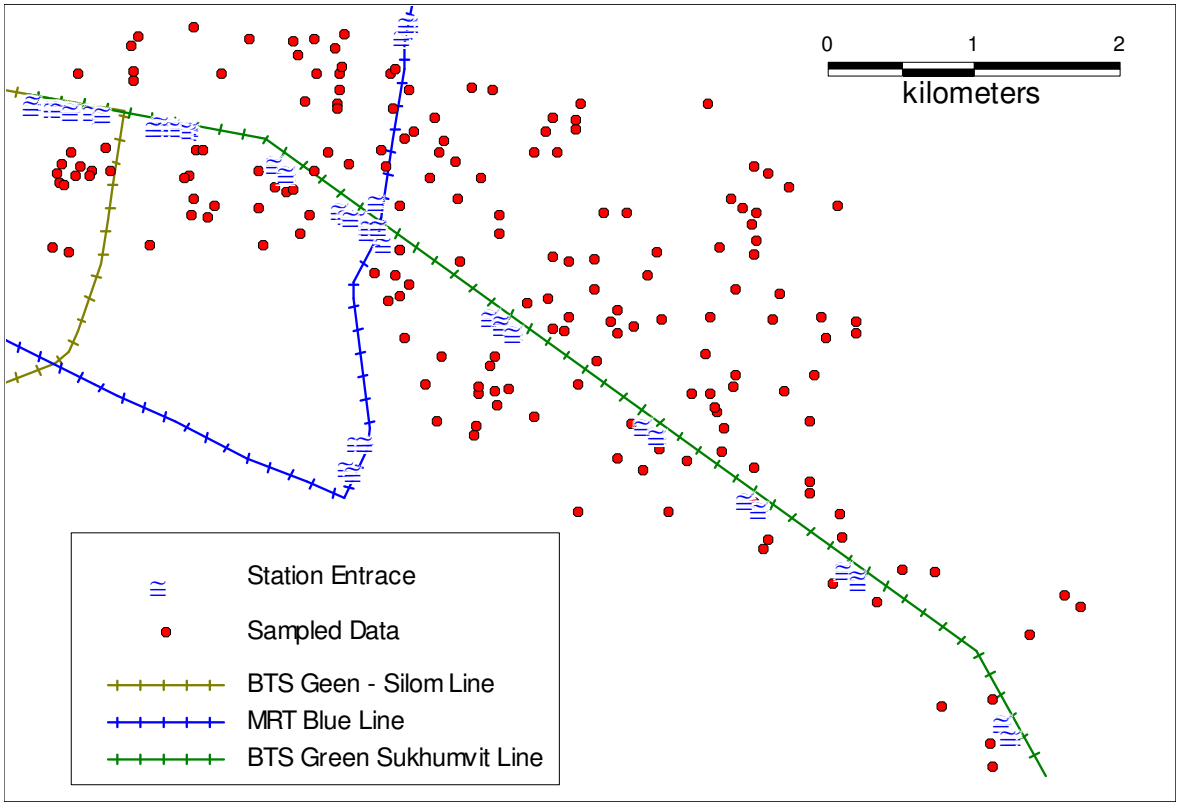


Figure 2 Locations of the Sample Data

Following the local norms, in this study, units for sale are called condominiums and those for rent are called apartments. For each unit the survey collected the characteristics of the building such as age, number of floors, and total floor space; the characteristics of the unit being advertised for sale or rent such as price, floor location, and amenities; and the physical distance to major facilities such as railway station, hospital, and school. The data items are summarized in Table 1.

IMPACT OF URBAN RAIL

Land Value

This study investigated the publicly assessed land value at representative locations along the two major road corridors, namely, Sukhumvit Road, on which the median of the elevated BTS railway is located; and Petchburi Road, a nearby road where railway service is not available. The changes in the land values of several road sections connecting to Sukhumvit Road are compared to those of Petchburi Road. Figure 3 shows the result.

Table 1 Sample Data Items

Name	*Description*
NAME	Name of condominium or apartment
SOI	Name of road
BLDG_UTM_X	x coordinate in UTM system
BLDG_UTM_Y	y coordinate in UTM system
BLDG_FLRSPC	Total usable floor area of building (sq.m.)
BLDG_STOREY	Number of floors of building
BLDG_TYPE	Building type (condominium or apartment)
BL_AGE	Age of building (years)
UNIT_SIZE	Floor space of unit (sq.m.)
UNIT_FLR	Floor location of unit
UNIT_BED	Number of bedrooms in unit
UNIT_BATH	Number of bathrooms in unit
UNIT_LIVING	Number of living rooms in unit
UNIT_KITCH	Number of kitchens in unit
UNIT_MAID	Number of maid rooms in unit
UNIT_PRICE	Sale price or rent of unit (baht)
UNIT_FACFEE	Common facility fee (baht)
UNIT_FURNISH	Furnished or not (dummy)
DIST_MAINRD	Distance to main road (m)
DIST_BTSMRT	Walking distance to nearest BTS or MRT station (m)
DIST_HOSPTL	Distance to nearest hospital (m)
DIST_SCHOOL	Distance to nearest school (m)
DIST_SHOPNG	Distance to nearest shopping center (m)
DIST_CONVST	Distance to nearest convenience store (m)
DIST_BANK	Distance to nearest bank (m)

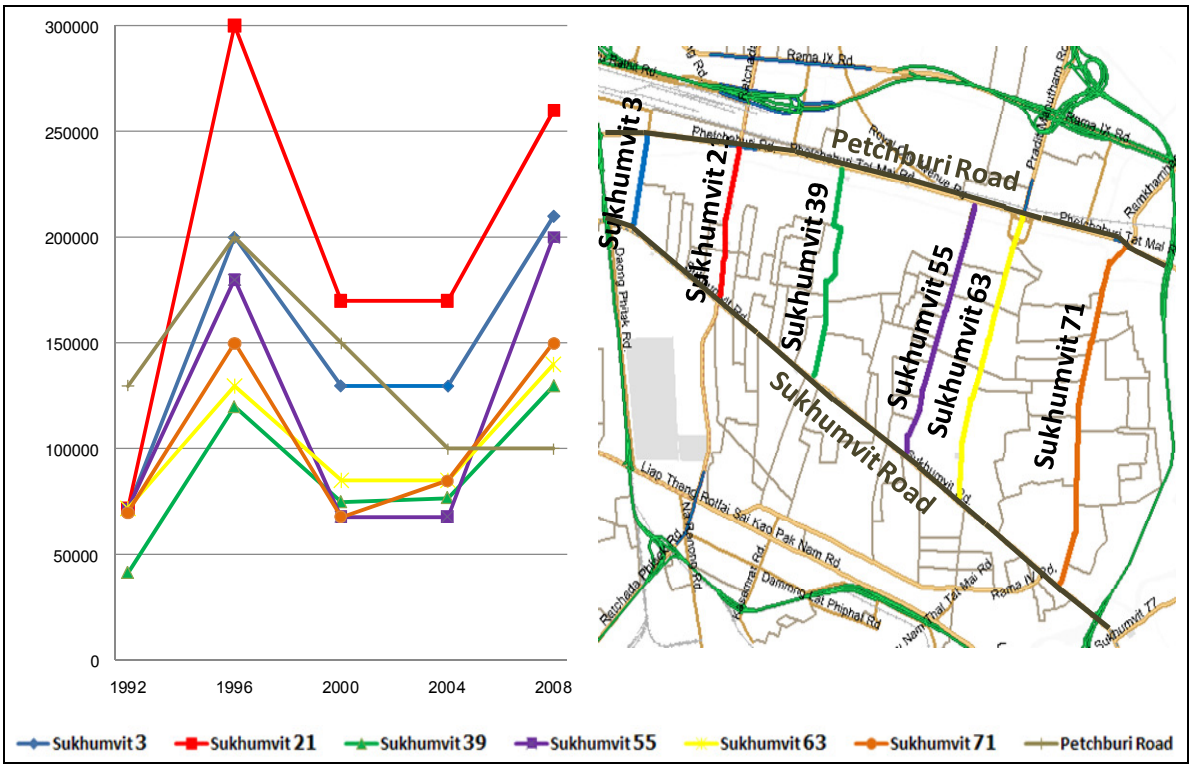


Figure 3 Changes in Assessed Land Values

The land values increased from 1992 but dropped during the economic recession from 1997 to 2004. Since then, land values along the roads connecting to Sukhumvit Road, i.e., subroads 3, 21, 39, 55, 63, and 71, have become more valuable while those of Petchburi Road have not. It is hypothesized that these increments are due to the BTS railway line along Sukhumvit Road. In other words, the land-value increase is probably caused by the rail transit service.

Building Stock

The study investigated the changes in the building stock in the study area. We investigated the existing tall buildings, including office buildings, hotels, and condominiums, in the area along Sukhumvit Road. They are presented in Fig. 4 in three-dimensional graphics with the aid of Google Earth and Google SketchUp. The figure shows the BTS railway line and its three stations, located about 1 km apart: Phrom Phong, Asoke, and Nana. The buildings can be classified into three groups by age. The first group consists of those existing in 1992 before BTS, colored green. The second group includes those built during the BTS construction from 1992 to 1998, colored red. The third group includes those constructed after BTS opened in 1998, colored blue.

A visual inspection shows that many buildings were constructed after the rail transit development. This is claimed to be caused by the BTS development, which brings many benefits to the area. In the past, certainly before the BTS project, Asoke intersection was one of the most congested intersections in Bangkok; its surrounding area had inevitably become

less accessible and valuable because of the traffic congestion. Now that BTS provides a high level of public transport service, the Asoke area has become attractive to developers. Previously unfinished buildings have been completed and abandoned buildings have been renovated. Modern office buildings, high-rise condominiums, and luxury hotels are appearing, as indicated by the blue buildings in Figure 4. Asoke is therefore a major beneficiary of the railway development. It is now a transfer-station area where the BTS and MRT lines cross. Without BTS, Sukhumvit would be hugely congested because the new buildings attract huge travel demands.

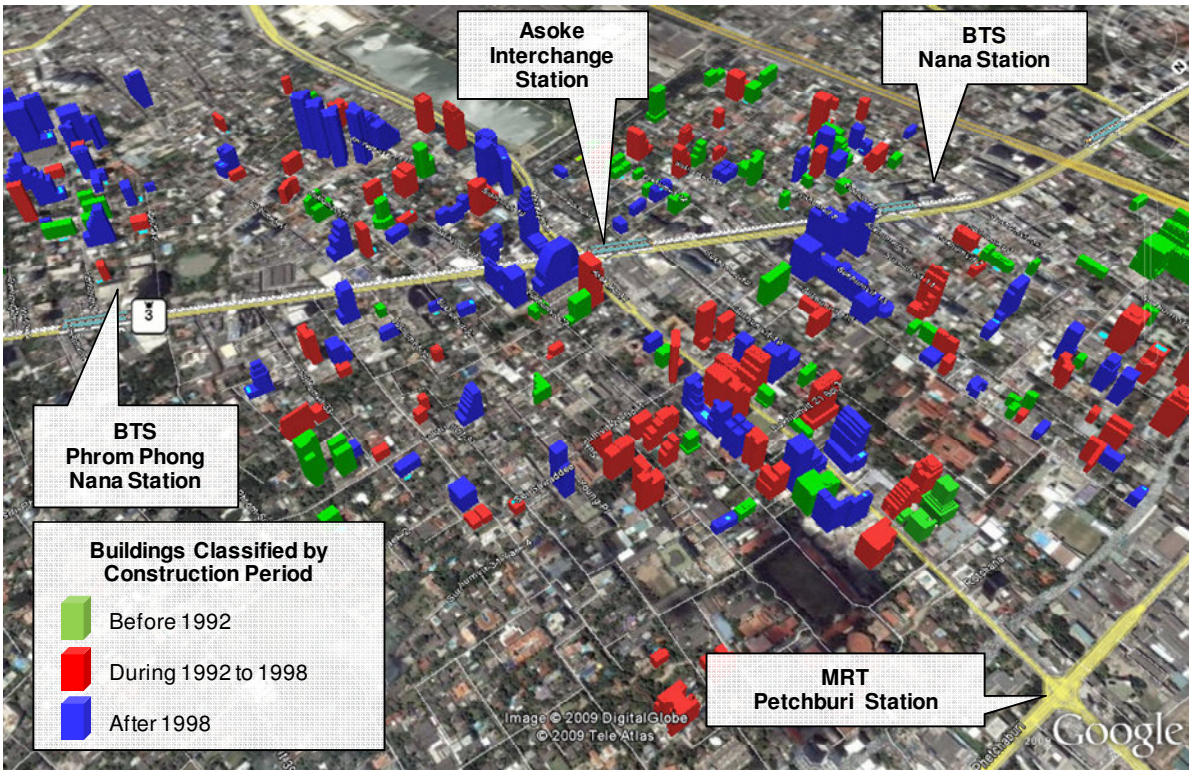


Figure 4 Buildings in 2009 Colored by Its Construction Period

The cumulative numbers of buildings and the cumulative floor space, or the so-called building stock, are shown in Figure 5. It is obvious that the building stock has grown rapidly as a result of the BTS development. This is compared with the building stock of nearby Petchburi Road, where rail transit is not available. Starting from nearly the same numbers in 1992, before BTS started construction, the building stock along Petchburi Road is much less than that of Sukhumvit Road because there was less interest from developers, i.e., the customers in the real-estate market.

This section has shown via real evidence that urban rail transit has played a significant role in shaping urban land development in Bangkok. It is interesting to examine exactly what drives up the property values after the railway development. Our hedonic study of the property values will be described next.

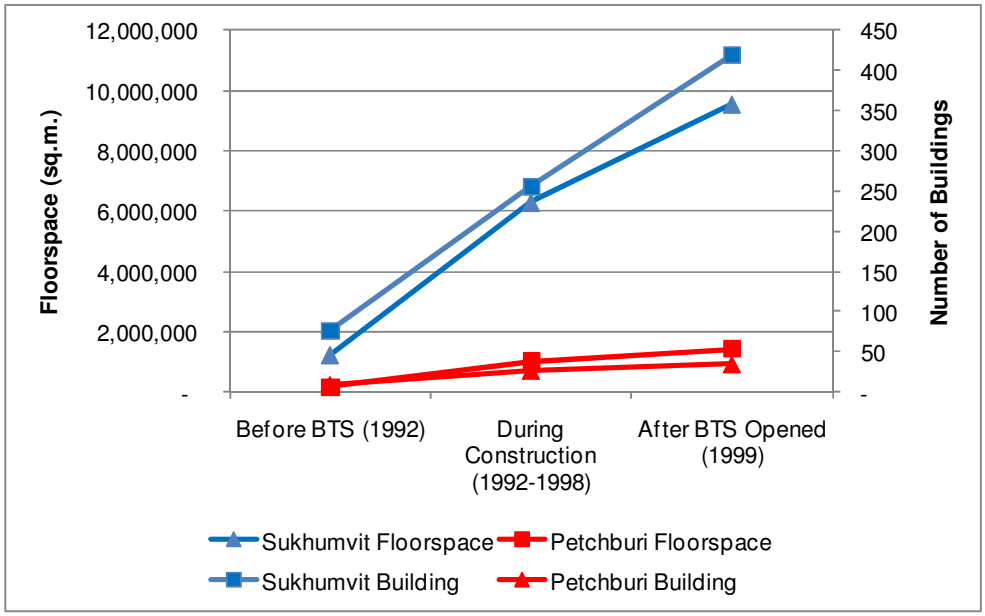


Figure 5 Building Stock along the Two Corridors

HEDONIC PRICE MODEL

The term hedonic is used in economics, especially in real-estate (property) economics, to estimate demand or prices as a combination of separate components, each of which may be treated as if it had its own market or price. In the context of regression, these separate components are often treated as independent variables in the modeling process. The classical hedonic approach has been widely used. For example, in Shanghai a simple hedonic regression showed the land-value premium of proximity to a train station (Pan and Zhang, 2008). In San Diego a model showed that access to a highway has a significant effect on office rent while access to the LRT does not (Ryan, 2005). A model for Bogota showed that walking access to the BRT has a great impact on property values (Raskin, 2007).

Some studies have taken into account the neighborhood effects. The neighborhood composition has a large influence on land value in California (Cervero and Duncan, 2004). In Seoul, Korea, a simple hedonic model indicated that the distance to the Line-5 subway station has less impact than other factors such as the quality of the school district, the proximity to a high-status subcenter, and accessibility to recreational resources (Bae et al., 2003). A model with spatial lag has been proposed to analyze the impact of transportation accessibility on residential property values in Seoul (Shin et al., 2007). In Bangkok, Thailand, a spatial autoregressive regression model has been proposed to examine the impact of the BTS urban railway on property prices (Chalermpong, 2007). In Buffalo, NY, the impact of the LRT in New York on station-area property values was determined using an individual regression model for each of the 14 LRT stations (Hess and Almeida, 2007). The effects were not felt consistently throughout the system. The proximity effect is positive in high-income station areas but negative in low-income station areas.

This study presents a spatial hedonic analysis of residential property values in the case study to determine the influential factors as well as the spatial variation. A classical model is used to select the explanatory variables, which include the proximity to transport and other activity attractions. The spatial variation of the influence on price is represented within a geographically weighted regression (GWR) framework.

Ordinary Least Squares Regression

Regression analysis is used to model the relationship between one (or more) dependent or response variables and a number of independent or predictor variables. The general regression model can be specified as follows:

$$y = \boldsymbol{X}\boldsymbol{\beta} + \varepsilon \tag{1}$$

$$E[\boldsymbol{\varepsilon}] = \mathbf{0} \tag{2}$$

$$\boldsymbol{\Omega} = E[\boldsymbol{\varepsilon}\boldsymbol{\varepsilon}'] = \sigma^2\mathbf{C} \tag{3}$$

where $\boldsymbol{y}$ is a vector (n×1) of observations corresponding to a dependent variable, **X** is a matrix (n×k) of observations of k independent variables, $\boldsymbol{\beta}$ is a vector (k×1) of regression parameters, $\boldsymbol{\varepsilon}$ is a vector (n×1) of errors, and **C** is a positive definite covariance matrix. The errors are often assumed to be normally distributed with an expected value of 0 and a variance-covariance matrix $\boldsymbol{\Omega}$ of size n×n. Classical ordinary least squares (OLS) is obtained by defining $\boldsymbol{\Omega} = \sigma^2\mathbf{I}$ and the solution for the coefficients is:

$$\hat{\boldsymbol{\beta}} = (\mathbf{X}'\mathbf{X})^{-1}\mathbf{X}'\boldsymbol{y} \tag{4}$$

Papers in urban studies have recently shed light on the local variation of the impact by incorporating nonstationarity: the situation where parameter estimates vary with the spatial entity used. For example, GWR has been used to examine the impact of transportation on land use by looking at local effects (Paez and Suzuki, 2001). Similarly, a study in Tyne and Wear, UK used GWR and found that nonstationarity existed in the relationship between transport accessibility and land value (Du and Mulley, 2006). It also showed that transport accessibility may have a positive effect on land value in some areas but in others a negative effect or no effect. The conclusion was that a uniform land-value capture would be inappropriate. Based on the GWR framework, a nonstationary spatial interpolation method has been proposed in which spatial autocorrelation and nonstationarity are accommodated (Vichiensan et al., 2006).

Geographically Weighted Regression

GWR (Fotheringham et al., 2002) is the term used to describe a family of regression models in which the coefficients, **β**, are allowed to vary spatially. The regression model in Eq. (1) may be rewritten for each local model at observation location o as follows:

$$y_o = \boldsymbol{X}_o \boldsymbol{\beta}_o + \varepsilon_o \tag{5}$$

where the subscript *o* indicates an observation point used to estimate the model parameters. The coefficients $\boldsymbol{\beta}_o$ are determined by examining the set of points within a well-defined neighborhood of each of the sample points. This neighborhood is essentially a circle, radius *r*, around each data point. However, if *r* is treated as a fixed value in which all points are regarded as of equal importance, it could include every point (for r large) or alternatively no other points (for r very small). Instead of using a fixed value for r, we use a distance-decay function, *f(d)*. Various functional forms of *f(d)* are available. For example, $f(d) = \exp(-d^2/h)$, where *d* is the distance between the focus point *o* and other data points, and *h* is a parameter (also called the bandwidth). A small bandwidth results in a rapid distance decay, whereas a larger value gives a smoother weighting scheme. This parameter may be defined manually or alternatively by an adaptive method such as cross-validation minimization or minimization of the Akaike information criterion (AIC). Following the framework of Eq. (3), the variance-covariance matrix for the GWR model may be defined as:

$$\boldsymbol{\Omega}_o = E[\boldsymbol{\varepsilon}_o \boldsymbol{\varepsilon}_o] = \sigma_o^2 \mathbf{C}_o \tag{6}$$

The diagonal elements of matrix $\mathbf{C}_o$ are given by

$$g_{oi}(\gamma_o, d_{oi}) = \exp(\gamma_o d_{oi}^2) \tag{7}$$

and the off-diagonal elements are all equal to 0.

The variance is defined as a function of two parameters, namely σ_o^2 and γ_o, and d_{oi} is the distance between focal point *o* and observation *i* (=1,…,n). The advantage of using an exponential function such as (7) is that the *i*th diagonal element of the covariance matrix $\omega_{oi} > 0$ provided $\sigma_o^2 > 0$, thus ensuring positive definiteness. Assuming normally distributed errors with a variance-covariance matrix as in (6) and (7), the local parameter estimates can be obtained:

$$\hat{\boldsymbol{\beta}}_o = (\mathbf{X}'\mathbf{C}_o^{-1}\mathbf{X})^{-1}\mathbf{X}'\mathbf{C}_o^{-1}\boldsymbol{y} \tag{8}$$

$$\hat{\sigma}_o^2 = \frac{1}{n}(\boldsymbol{y} - \mathbf{X}\hat{\boldsymbol{\beta}}_o)'\mathbf{C}_o^{-1}(\boldsymbol{y} - \mathbf{X}\hat{\boldsymbol{\beta}}_o) \tag{9}$$

These are conditional on the structure of matrix $\mathbf{C}_o$. These estimators, when substituted and introduced into the corresponding log-likelihood function, result in a concentrated function that depends on a single parameter, namely γ_o:

$$-\frac{n}{2}\ln\left[\frac{1}{n}(\boldsymbol{y} - \mathbf{X}\hat{\boldsymbol{\beta}}_o)'\mathbf{C}_o^{-1}(\boldsymbol{y} - \mathbf{X}\hat{\boldsymbol{\beta}}_o)\right] - \frac{1}{2}\sum_{i=1}^{n}\gamma_o d_{oi}^2 \tag{10}$$

The above function can be numerically maximized with respect to γ_o to obtain a parameter that can be substituted into (10) to obtain the maximum likelihood estimates for $\hat{\boldsymbol{\beta}}_o$. This paper considers the nonstationarity in the hedonic price model parameters and presents a hedonic price model within the GWR framework. The model parameters are estimated in

reference to an OLS model. The coefficient parameters can be estimated using Eqs. (4), (8), and (9). The bandwidth kernel is solved by maximizing the function in Eq. (10).

RESULTS

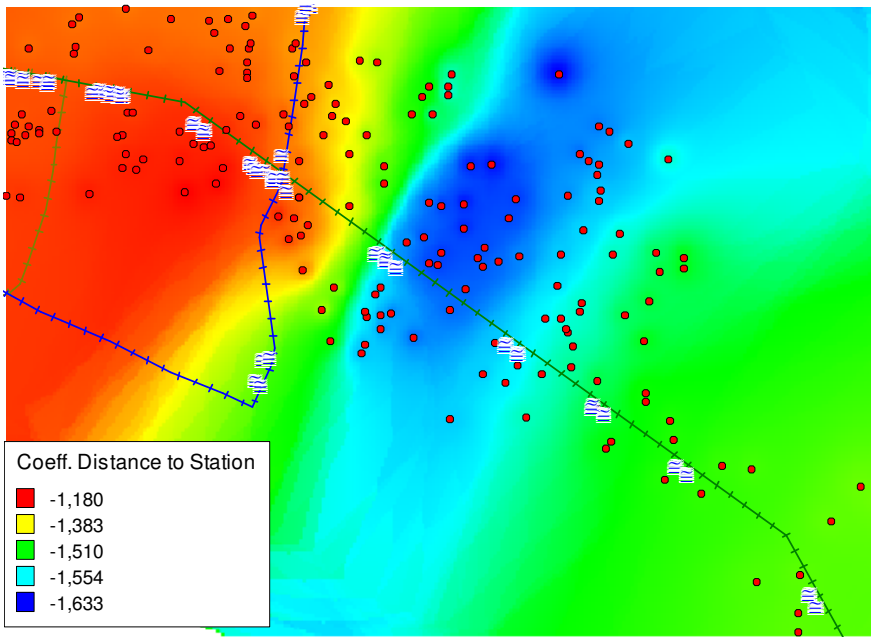
The OLS and GWR models were coded in MATLAB, and the results are shown in Table 2. Consider the OLS model where the estimation is global or constant over the study area. Several data items from the field survey were tested in the estimation, but only three of them were statistically significant: size, floor location, and distance to MRT. The impact of the unit size is intuitive because a larger unit is likely to be more expensive than a smaller one. The floor location has a positive coefficient, meaning that a unit located on a higher floor is more expensive. This premium is probably a result of better scenery and a wider opening space. The proximity to the BTS or MRT station has a negative coefficient indicating that a property located closer to the station will be more valuable because of its convenience for commuting and traveling.

Table 2 Model Parameters

	OLS		*GWR*		
	Coefficients	*t-Stat*	*Coefficients*		
			min	*max*	*mean*
(Constant)	1,602,257.76	1.954	-314,532.14	1,669,666.50	964,616.84
UNIT_SIZE	62,335.84	16.152	61,641.54	68,919.43	63,776.29
UNIT_FLR	157,033.13	3.809	145,386.32	189,442.46	161,437.56
DIST_BTSMRT	-1,561.79	-2.325	-1,633.13	-1,178.64	-1,422.51
Number of observations	180		180		
Number of parameters	4		5		
AIC	5981.6		5994.6	6017.0	6007.4

Using the statistically significant coefficients suggested by the OLS model, the GWR model parameters are estimated. Since the GWR model is different at each data point, the number of parameter sets is equal to the number of data points available, i.e., there are 180 sets of parameters. For ease of presentation, the GWR results are presented using three representative statistics: minimum value, maximum value, and mean of the coefficients, shown in Table 2. The GWR estimates have the same trend seen for OLS. The model's goodness-of-fit is evaluated by the AIC, which is based on the value of the likelihood function and considers the trade-off between the information obtained and the number of variables used. The GWR model outperforms the OLS, indicating that the nonstationarity has played a significant role in improving the model's goodness-of-fit. In other words, the effect of each explanatory variable on the property value varies spatially in the study area. To illustrate this, the coefficients are interpolated by the inverse distance weighting method with the aid of MapInfo. The interpolated coefficient surfaces of two variables are shown in Figure 6. Obviously, the coefficients vary substantially within the study area, indicating that there is a varying spatial relationship, i.e., nonstationarity in the model parameters.

a) Distance to Railway Station



b) Unit Size

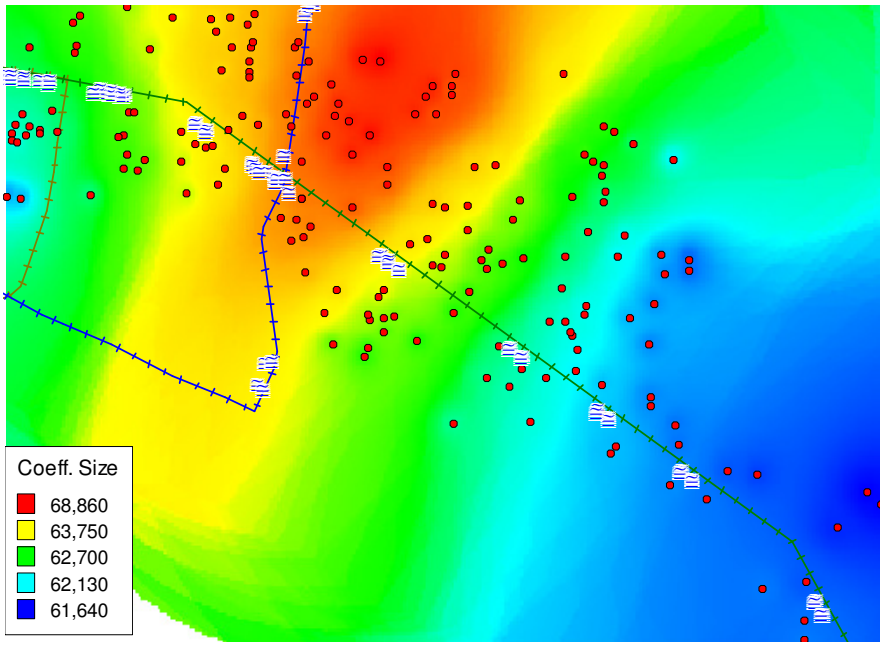


Figure 6 Spatially Varying Influence to Property Value: a) Distance to MRT, b) Unit Size

A closer look at the variation in the distance to the railway station (Figure 6a) revealed that the price of properties is less sensitive to station proximity in the red area, a high-density business area around Asoke transfer station, than in the blue area, a semi-commercial/residential area around Phrom Phong station where the station access by

walking or motorcycle-taxi is poor. This makes the distance more important to a buyer. On the other hand, the station access in the outer residential area, shown in green, is more convenient by means of various paratransit options because travel is faster in this less-congested area. As a result the property loses less value although it is located further from the stations. Therefore, the variation in the relationship between station distance and property value is caused by the ease of station access. This information could help the local government or the transport operator to make effective improvements to the station area. Likewise, variation of the size coefficient in Figure 6b is intuitive. It is a consequence of the locational convenience around Asoke transfer station, i.e., in the red area in the map. This makes these properties more valuable than other properties at similar prices.

CONCLUDING REMARKS

This paper has empirically shown that rail transit has a large influence on residential property values; this is indicated by the increasing land values and building stock in the case study. It is furthermore found that the impact is quite complicated and spatially varied. A spatial hedonic study has been presented. The global model, OLS, suggested the influencing factors. The local model, GWR, revealed the varying relationships between property values and those factors. The ease of station access varies substantially along the railway corridor. This may be typical of many cities in developing countries. Previous studies in the literature mostly interpreted the coefficients as a premium of the location, considering what determines the price. This paper instead looked at the coefficient variation as a reflection of the circumstances in the study area, considering what information is given by the price. This information will be useful to concerned parties such as real-estate developers and the railway operator, as well as to general customers.

ACKNOWLEDGEMENTS

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