Article Journal of Asian Geography, 2022, Volume 1 (Issue 1), 40-47.

Estimating the Impact of Mass Rapid Transit (MRT) on Residential Property Prices in Greater Kuala Lumpur, Malaysia

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Received: 16 Aug 2022; Revised: 7 Sep 2022; Accepted: 7 Sep 2022; Published: 21 Sep 2022

Abstract: Investments in new MRT infrastructure in Greater Kuala Lumpur, Malaysia involved a large portion of the government's fiscal expenditures. Hence, identifying the impact of this infrastructure on residential property prices, which includes timing and spatial extent is important for the potential implementation of alternative mechanisms for funding this investment. Whilst there has been substantial research into the impact of urban rail transit on property prices, these studies generally deal with developed Western countries, and there is limited research of this sort on developing countries. Using a hedonic pricing model, this study, therefore, estimates the impact of proximity to the new SBK MRT line on residential property prices in Greater Kuala Lumpur, Malaysia. To draw meaningful conclusions regarding the positive and negative impacts of the MRT on residential property prices, temporal and spatial dimensions were considered. Thus, both longitudinal and cross-sectional effects were estimated in a single model. This innovative approach allows us to compare changes in property prices before and after the MRT line became operational. The multi-band catchment areas of 0–0.4 km (the treatment zone) and 0.85–1.5 km (the control zone) from the nearest station were used. The results presented in this study indicate that a typical condominium/service residence unit located within 0.4 km (the treatment zone) from the nearest MRT station and transacted after the system was operational on the northwest side of the city could earn a premium of approximately 9.5%, or RM 99,874 of the city's mean home price, while a typical similar property located within the same distance from the nearest MRT station but transacted before (during construction, to be precise) the system was operational could generate a premium of about 6%, or RM 63,078 of the city's mean home price, compared to those outside of this distance. Findings from this study have significance for the potential implementation of a land value capture policy as an alternative source of revenue to fund or partially fund urban rail transport in Greater Kuala Lumpur, which is totally neglected.

Keyword: Urban transport; Mass Rapid Transit (MRT); hedonic pricing model; land value capture; Klang Valley; Malaysia.

1.0 Introduction

Transportation facilities, especially major transportation facilities such as highways and urban rail transit systems, play a pivotal role in enhancing productivity and quality of life, particularly in larger and denser metropolitan areas such as Greater Kuala Lumpur, Malaysia. Since the mid-1990s, the Malaysian government has spent billions of dollars to fund the construction of several types of urban rail transit systems in Greater Kuala Lumpur, the most recent of which is mass rapid transit (MRT); it is often credited with positive externalities such as improved accessibility and economic development and reduced traffic congestion and air pollution from private vehicles. Other indirect benefits of urban rail systems have also been examined.

The classical urban land economics theory posits that there is a strong relationship between land value and transport cost – with improved accessibility to the city centre, the land value increases because of the decreasing transport cost (Alonso, 1964; Muth, 1969; Mills, 1972). Indeed, the improved accessibility provided by urban transport can potentially drive up the price of nearby land due to increased buyer demand. Hence, over the past 50 years, numerous studies have been conducted to demonstrate this relationship. For example, in North America, Chen et al. (1998) examined the effects of LRT on the prices of nearby single-family homes and found that LRT has both positive (accessibility) and negative (nuisance) effects on prices. They conclude that the positive effects outweigh the negative, with the minimum price estimated at 427.33 metres from the nearest station, a difference of 10.5%. Bowes and Ihlanfeldt (2001) found that properties within a quarter of a mile were 19% lower than properties three miles away or more. Duncan (2008) reported that single-family homes and condominium units experience a price premium of 6% and 17%, respectively when located near urban rail transit stations. Using a geographically weighted regression (GWR), Dziauddin et al. (2015) estimated the spatial distributional of LRT effects on the residential property prices in Greater Kuala Lumpur and found that the LRT system has indeed added premiums on residential property prices but with spatial variation over a geographical area. Consistent with these findings, more recent studies by Diao et al. (2017), Li et al. (2017), Forouhar and Hasankhani (2018), Li (2018), Mulley et a. (2018), Dziauddin (2019), Yen et al. (2019), Yang et al. (2020) and Schmidt et al. (2022) have also found significant positive relationships between rail transit systems and residential property prices. However, Du and Mulley (2006), Hess and Almeida (2007), and Hewitt and Hewitt (2012) have found less profound but still significant positive effects of rail transit on property values in Ottawa (Canada), Tyne and Wear (the United Kingdom), and Buffalo (New York, USA). Moreover, Ke and Gkritza (2019) have found positive effects of rail transit during the announcement phase on the single-family home prices as the distance to the nearest LRT station decreases, but the price of properties decreases after the system began operations. They attributed these findings to speculation that may have resulted from the announcement of the LRT system, while homeowners living closest to the stations after the system began operations may have viewed the LRT system more as a nuisance than a benefit. In a case study of Tyne and Wear Light Rail Transit Metro, Pearson et al. (2022) revealed that property prices increased immediately after the extension of Sunderland Metro becomes operational in 2002, though no statistically significant results were found 15 years later.

Besides positive externalities, urban rail transit systems can also create negative externalities such as noise pollution, visual obstruction, and congestion along rail lines and near stations, especially for those who are extremely close to this infrastructure. As people place increasing importance on their physical and mental health, concerns like noise, vibration, visual obstruction, and traffic congestion can become important factors in home-buying decisions and be expressed in residential property price differentials. Studies conducted by Debrezion et al. (2006), Hewitt and Hewitt (2012), Kilpatrick et al. (2007), and Nelson (1992) show that living too close to urban rail transit systems may depress property prices, owing to noise pollution (during both construction and operations), visual pollution, and congestion. Nelson's (1992) study of Atlanta, Georgia shows that properties located in high-income neighbourhoods were negatively affected by transit stations. Debrezion et al. (2006) showed a negative effect of proximity to railways, with properties located within 250 metres of a railway line priced 5% lower than locations farther than 500 meters away from a line. They attributed this negative relationship to noise effects. Likewise, Kilpatrick et al. (2007)

 E-ISSN: 2948-5231

found that proximity to a transit corridor alone – that is, without direct access – had a negative impact on nearby property prices. A 2012 Hewitt and Hewitt study revealed that residential property prices were positively affected in some areas and negatively in others by distance from O–Train stations in Ottawa, Canada. Hewitt and Hewitt (2012) reported that many neighbourhoods closest to the route experienced a negative impact on residential property prices, while areas located farther away experienced a significant increase.

Based on the above discussion it can be concluded that the empirical evidence tends to support the value uplift from urban rail transit investment. Using the Sungai Buloh–Kajang (SBK) MRT Line in Greater Kuala Lumpur, Malaysia as a case study and hedonic pricing model, this research aims to estimate the impact of MRT on residential property prices, more specifically condominium/service residence. To draw meaningful conclusions regarding the impact of the MRT on residential property prices, temporal and spatial dimensions were considered. Thus, both longitudinal and cross-sectional effects were estimated in a single model. This innovative approach allows us to compare changes in property prices before and after the MRT line became operational. The distance to the nearest station represents the distance to the nearest station and nearest line in mid–December 2016, as the line operated from Sungai Buloh Station to Semantan Station on 16 December 2016. Multi-band catchments were used to estimate the impact of the MRT line on residential property prices. The multi-band catchment areas of 0–0.4 km (the treatment zone) and 0.85–1.5 km (the control zone) from the nearest station were used. Hence, the research contributes to the empirical evidence by addressing both longitudinal and cross-sectional effects in a single model.

The remaining sections of this paper are structured as follows: Section 2 presents the study area. Section 3 discusses materials and methodology, while Section 4 presents empirical results. Finally, Section 5 discusses the empirical results and Section 6 concludes the discussion.

2.0 Study Area

This study uses the SBK MRT line in Greater Kuala Lumpur as the case study. The Greater Kuala Lumpur region is a conurbation that constitutes the Federal Territory Kuala Lumpur, Gombak, Petaling, and Hulu Langat. This region has a population of around 8.42 million people as of 2022 and is not only a rising urban hub in South-East Asia but a melting pot of cultural differences and diversity. Generally, the population of Greater Kuala Lumpur has been equally distributed across geographical areas. Over the past 30 years or so, Greater Kuala Lumpur has experienced rapid development and modernisation, with significant developments of various business centres and the erection of major building landmarks.

At an estimated contract value of RM36 billion, the SBK MRT Line is the ninth urban rail transit line that connects the rapidly developing major towns of Sungai Buloh in the northwest of Kuala Lumpur with Kajang in the southeast. The aim of the project was not only to expand the Malaysian capital's inadequate rail network but also to integrate existing rail networks; it was expected to help alleviate the severe traffic congestion afflicting Greater Kuala Lumpur. More importantly, the project was expected to improve accessibility and connect two major towns (Sungai Buloh and Kajang) through the Kuala Lumpur CBD by providing high-quality, rail-based public transport that is affordable, reliable, fast, and safe. Furthermore, the location and route suggest that planners hoped to revitalise urban neighbourhoods such as Sungai Buloh, Kota Damansara, Mutiara Damansara, Damansara Utama, Taman Tun Dr. Ismail, and Cheras with the introduction of an MRT line. From a socioeconomic perspective, it can be observed that the higher-income groups formed in the northwest of Kuala Lumpur which include Sungai Buloh, Kota Damansara, Mutiara Damansara, Damansara Utama, Taman Tun Dr. Ismail and Pusat Bandar Damansara, while the majority of middle and lower-income groups formed in the southeast of Kuala Lumpur which include Cheras, Bukit Dukong, and Kajang.

The 46-kilometre route with 31 stations runs for 9.5 kilometres beneath the Kuala Lumpur CBD. Figure 1 shows the SBK MRT Line. The proposal to construct the infrastructure was announced in 2010 and approved by the government in December of that same year. It began full service in 2017 at a cost of RM23 billion. Since full service began on July 17, 2017, ridership has grown from 22.35 million in 2017 to 51.31 million the following year and nearly 64 million in 2019 (A. Malek, 2020). As the SBK MRT Line serves large urban neighbourhoods, it provides an appropriate opportunity to estimate increases in residential property prices as a result of investment in urban rail infrastructure.

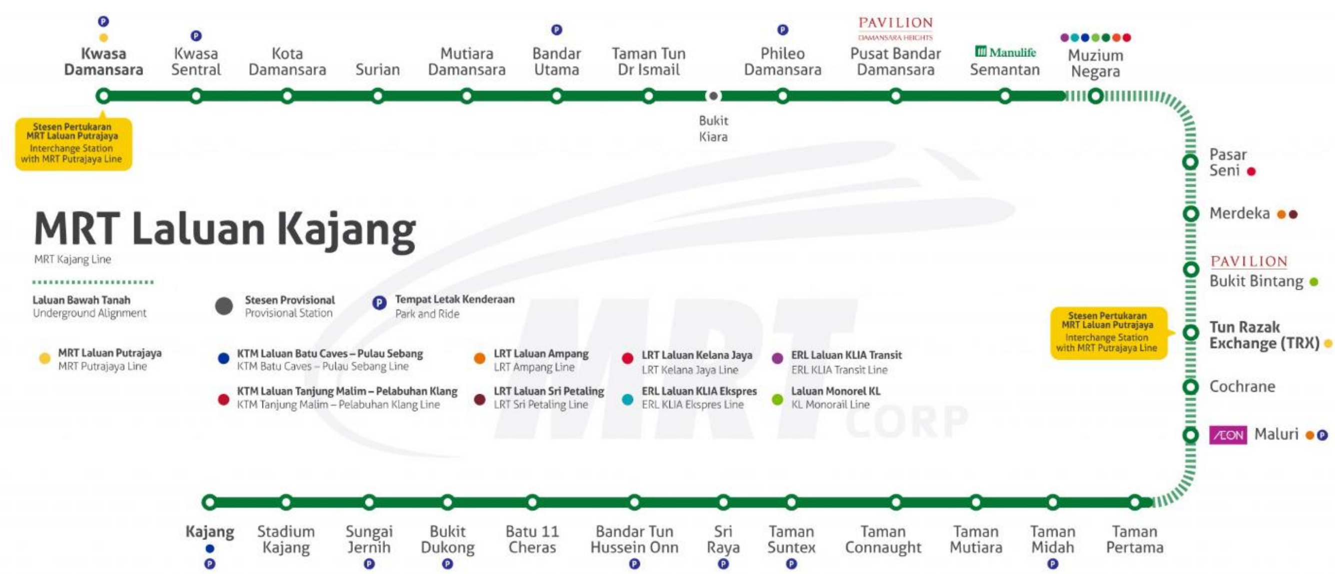

Figure 1: The SBK MRT line and its stations.
Source: www.mymrt.com.my

3.0 Materials and Methodology

3.1 Materials

The data used for this study are condominium/service residence transaction records obtained from the Brickz website (https://www.brickz.my), which collates information from the Malaysian Department of Valuation and Property Services. The database contains

E-ISSN: 2948-5231

complete transaction records for the years 2012 to 2020; however, considering the instability of the 2020 real estate market due to the COVID-19 pandemic, only residential transaction records from 2012 to 2019 were included in the study. It should be noted that, for analysis purposes, the 23 transaction records of 2012 were combined with the 2013 data. The reason for this is that there are too few to retain for statistical analysis and so were combined for the model estimation. The first part of that time frame, 2012 to 2016, represents the period when the SBK MRT Line was still under construction. Although the database contains transaction records for residential properties for the entire Greater Kuala Lumpur region, only those within a two-kilometre catchment area along the SBK MRT Line were selected for inclusion in the sample. While previous empirical evidence suggests that the increase in the value of residential properties was significantly higher when they were located within 0.8 kilometres of the nearest station, the present study estimates the impact beyond that range. In addition to the transaction price, date of sale, residential address, building type, ownership, floors, rooms, and built-up area data were also obtained. The only important information not gathered from this source was the age of the house, which was obtained through Internet searches on websites like Star Property (https://www.starproperty.my) and Property Guru (https://www.propertyguru.com.my). The use of internet searches for house age was guided by a previous study conducted by Seo et al. (2019) where they obtained additional independent variable data via the internet. Moreover, the Star Property and Property Guru websites are considered reliable internet sources for online property portals.

For selecting the sample for the hedonic pricing model, Tse and Love (2000) noted that factors such as similar locational characteristics and income groups that are supposed to have homogeneous tastes should be considered so that the net effects of physical and locational characteristics of the neighbourhood are similar. For the present study, condominium/service residences located in areas consisting of Kota Damansara, Mutiara Damansara, Bandar Utama, Taman Tun Dr. Ismail and Phileo Damansara, were selected as a sample. These areas were selected based on factors cited above, and the generous distribution of housing estates and house price transaction records. In total, 907 condominium/service residence transaction records were collected.

After accurately situating the data sets on a local map, buffers of 2.0 kilometres were created along the SBK MRT Line using the Buffer feature available in the QGIS Desktop 3.22.0 software package. According to Tse and Love (2000), a feasible approach in using the hedonic pricing model is not only to select a sample with similar locational characteristics and income groups but also to select one with relatively similar physical characteristics such as house type and floor area, along with the price. Ultimately, 604 transaction records of condominium/service residences were selected for the final analysis. In addition to the structural characteristics, a set of variables for locational characteristics such as distance to the nearest MRT station (focus variable), secondary school, shopping centre, commercial area, and park were also included. The inclusion of these variables in the model was guided by previous studies conducted by Hess and Almeida (2007), Seo et al. (2014), Li et al. (2017), Dziauddin (2019), Yang et al. (2019), and Yen et al (2019). For the shopping centre, a further designation was made for the main shopping centre, based on its size and reputation. This shopping centre is One Utama. The distance in metres from each condominium/service residence was measured along the street network by using Google Maps. This allowed the shortest walking route from each condominium/service residence to the locational attributes can be measured accurately. As Mills and Hamilton (1994) argued in an urban context, accessibility advantages along transport facilities corridors should create a locational advantage and thus help motivate individuals and businesses to outbid one another for land and buildings around a station. To estimate the locational advantage for land and buildings around the station, proximity to the nearest station has been used by previous studies (Hess & Almeida, 2007; Seo et al, 2014; Dziauddin et al., 2015; Li et al., 2017; Mulley et al., 2018; Yen et al., 2019; Dziauddin, 2019; Yang et al., 2019; Pearson et al., 2022).

Table 1 provides the summary statistics of dependent and independent variables employed in this study. The mean value of condominium/service residence prices in this study is 1.05 million Malaysia Ringgit with a standard deviation of nearly 0.47 million (44.6% of the mean). In terms of the floor area, the average condominium/service residence has a floor area of around 1,523.21 square feet with a standard deviation of 440.87. However, there are units as low as 1,000 square feet to as large as 2,973 square feet. The mean age of the units is 7.35 years with a standard deviation of 3.70. The definition of various independent variables used for the final model estimation is shown in Table 2.

Table 1: Descriptive statistics of dependent and independent variables

	Mean	Standard deviation	Minimum	Maximum
Condominium/service residences price (Ringgit Malaysia)	1,050,470.30	468,776.00	603,000.00	3,600,000.00
Area (sq.feet)	1,523.21	440.87	1,000.00	2,973.00
Age	7.35	3.70	0.00	17.00
One Utama shopping centre (metre)	2,276.35	967.36	662.60	4,498.39

In a hedonic pricing model, dummy variables are commonly used to deal with discontinuous factors (Tse & Love, 2000). Thus, for a condominium/service residence unit that possesses the characteristics of freehold status, four or more bedrooms, located on ground level up to level five and level 20 and above, the dummy variables are given the value of “1”; otherwise, the value is “0”. To capture economic cycle effects and inflation on the residential property market, the transaction dates were transformed into a series of year indicator variables. Hence, seven dummy variables that represent “the year of transactions from 2013 to 2019” were introduced. The dummy variables take on the value of “1” if the property is sold in the respective years, and “0” otherwise. A series of dummy variables were included to capture the impact of MRT on residential property prices that are classified as “within a radius of 0-0.4 km and 0.85-1.5 km from the nearest station before and after its operations”, coded with the value of “1” or “0”.

Table 2: List of variables and their definitions

Short form	Independent variables (expected sign)	Definition of variables
PRICE	Price (dependent variable	Price in Malaysian Ringgit (RM)
AREA	Floor area (+)	Floor area in square feet
FREE	Freehold status (+)	1 if it has freehold status, 0 otherwise
AGE	Age (–)	From occupation permit date to year of sold (number of years)
BED	Bedrooms (+)	1 if it has four or more bedrooms, 0 otherwise
FLOOR1	Floor level (+/–)	1 if it is in ground level up to level 5, 0 otherwise
FLOOR2	Floor level (+/–)	1 if it is in level 20 and above, 0 otherwise
Y2019	Year 2019 (+)	1 if it is sold in 2019, 0 otherwise
Y2018	Year 2018 (+)	1 if it is sold in 2018, 0 otherwise
Y2017	Year 2017 (+)	1 if it is sold in 2017, 0 otherwise
Y2016	Year 2016 (+)	1 if it is sold in 2016, 0 otherwise
Y2015	Year 2015 (+)	1 if it is sold in 2015, 0 otherwise

E-ISSN: 2948-5231

Y2014	Year 2014 (+)	1 if it is sold in 2014, 0 otherwise
Y2013	Year 2013 (+)	1 if it is sold in 2013, 0 otherwise
TREAT1	Treatment 1	1 if it is within a radius of 0–0.4 km from the nearest MRT station before its operations, 0 otherwise
TREAT2	Treatment 2	1 if it is within a radius of 0–0.4 km from the nearest MRT station after its operations, 0 otherwise
CTRL1	Control 1	1 if it is within a radius of 0.85–1.5 km from the nearest MRT station before its operations, 0 otherwise
CTRL2	Control 2	1 if it is sold from the date of MRT started its operations, 0 otherwise
1UTAMA	One Utama shopping centre	Distance to the One Utama shopping centre

3.2 Methodology / framework / theory

As noted above, this study uses a hedonic pricing model (ordinary least squares) to estimate the impact of MRT on residential property prices. It is worth highlighting that the hedonic pricing model is a widely used and best method to identify house price effects related to factors such as proximity to transport facilities (Mulley et al., 2018; Li, 2018; Yang et al., 2019; Pearson et al., 2022). In addition, as Des Rosiers (2001: 150) noted, "the hedonic approach remains the most adequate tool for untangling the cross-influences between the numerous dimensions affecting property values and for establishing the implicit price of individual residential attributes". The general form of a hedonic pricing function can be specified as follows:

$$Y_i = f\ (S, L) + \varepsilon_i \qquad (1)$$

where,

Y_i = the price of property i;
P and L = the vectors of physical and locational characteristics, respectively;
ε_i = a vector of error terms.

Since the hedonic pricing model uses multiple regression analysis, it has to meet the following assumptions:

a. A linear relationship between dependent and explanatory variables;
b. No perfect multicollinearity among the explanatory variables;
c. The error terms (residual) are normally distributed with a mean of zero;
d. The error terms are independent (i.e., they are not autocorrelated); and
e. The error terms have constant variance (i.e., they are homoscedastic).

Following Orford (1999), any violation of these assumptions can lead to unreliable and biased parameter estimates; he stresses further that violations of assumptions four and five are common in many previous studies. In addition, errors are frequently caused by the misspecification of the model. Butler (1982) indicates that finding the best specification of the hedonic relationship for housing necessitates that one identifies both the best list of explanatory variables and the true functional form.

In all regression-based analyses, it is common to expect multicollinearity among two or more independent variables. To deal with this problem, the correlations between the independent variables used for the final models were determined using Pearson's correlation coefficient and VIFs. According to Orford (1999) and Neter et al. (1985), a Pearson correlation coefficient greater than 0.8 and a VIF greater than 10 indicates harmful collinearity.

To find the model that can best explain the relationship between house prices and their characteristics, the hedonic function must be properly specified. However, economic theory generally does not provide guidelines for choosing the functional form (Mulley, 2014; Tu, 2000). Therefore, the estimation process in the present study explored a number of different functional forms, such as linear, semi-logarithmic, and double-logarithmic. In other words, the process of identifying the 'best' functional form was an iterative process that involved different types of models and produced different types of results. A semi-logarithmic functional form was ultimately chosen because its residuals behaved better than the alternatives. The discussion in the following section is based on a semi-logarithmic functional form.

Another problem in regression analysis is a multivariate outlier, which refers to a combination of unusual values in at least two explanatory variables (Leys et al., 2019). The most common method for detecting multivariate outliers is the Mahalanobis distance, which is used in the present study. The equation for the Mahalanobis distance is as follows (Finch, 2012):

$$D^2_i = (x_i - \bar{x})' S^{-1}(x_i - \bar{x}) \qquad (2)$$

where x_i represents the vector of values on the set of p variables for subject i, $\bar{x}$ represents a vector of sample means on the set of p variables, and S represents the covariance matrix for p variables.

The analysis identified 10 extreme values (both highest and lowest) across the data set. To investigate whether the presence of these outliers could have an impact on the estimation results, two models were developed, one with outliers and one without. After comparing the results, these outliers were then removed, leaving 594 condominium unit transaction records for the final analysis. The final form of the semi-logarithmic used to estimate the impact of the SBK MRT Line on condominium/service residence units can be written as follows:

$$\log(PRICE) = \beta_0 + \beta_1(AREA) + \beta_2(FREE) + \beta_3(AGE) + \beta_4(BED) + \beta_5(FLOOR1) + \beta_6(FLOOR2) + \beta_7(Y2019) + \beta_8(Y2018) + \beta_9(Y2017) + \beta_{10}(Y2016) + B_{11}(Y2015) + \beta_{12}(Y2014) + \beta_{13}(TREAT1) + \beta_{14}(TREAT2) + \beta_{15}(CTRL1) + \beta_{16}(CTRL2) + \beta_{17}(1UTAMA) + \varepsilon \qquad (3)$$

where β_0 is the constant, β_i (for i = 1, 2, 3…, 17) are the regression coefficients, and ε is a vector of the error term that reflects the unobserved variations in house prices.

4.0 Results

Table 3 shows the summary statistics of Model 1, including a series of measures of fit such as the adjusted R^2, predictors, coefficients, standard errors, *t*-values, and indicators for the collinearity statistics tolerance and VIF. The model has relatively high explanatory power (0.823), implying that a considerable amount of the variation in the dependent variable is explained by this model with the expected positive and negative signs; this is largely in line with the findings of previous studies. The high value of *F* suggests that the model fits the data reasonably well.

Based on the tolerance and VIF values, it is safe to conclude that this model is free of multicollinearity. Of the 17 variables, 13 are significant at a minimum of 0.10%, except for BED, FLOOR1, FLOOR2, and CTRL1. Since this is a semi-logarithmic functional form, the interpretation of the estimated coefficients refers to their proportional (or, when multiplied by 100, their percentage) effects on prices. As expected, the coefficient on floor area (AREA) is highly significant not only among physical characteristics but also for all variables included in the final model, suggesting that floor area has a strong influence on property prices. Thus, *ceteris paribus*, each additional square foot of floor area leads to a 0.1% increase in price. The effects of the age of the property (AGE) and freehold ownership (FREE) are also noteworthy. Thus, *ceteris paribus*, for each year that the age of the property increases, property prices decreased by 2.8%, suggesting that property tends to become less expensive as it ages, while freehold ownership increased property prices by 18.5%.

As noted above, the year indicator variables were intended to capture two effects: local economic cycle effects and the existence and non-existence of the MRT system in the area. Property transactions in 2013 were not included in the final model to avoid collinearity. The model results for the year indicator variables are highly revealing. The model tells us that, of the six-year indicator variables, all have significant coefficients, and properties transacted after the MRT system began operating (2017–2019) are highly valued by homebuyers. So, *ceteris paribus*, the existence of the MRT system leads to a 27.9% (0.336 + 0.328 + 0.311 – 0.275 + 0.258 + 0.164 = 0.278) increase in prices.

Proximity to an MRT station implies greater accessibility, and the model results indicate that the effect of the MRT indicator variables is also notable. Of the four MRT indicator variables, three have significant coefficients with the expected signs (CTRL1 is the exception). The model results for MRT indicator variables suggest that there is a distinct price premium associated with distance to the nearest MRT station, with the premium decreasing or even turning negative as distance increases. *Ceteris paribus*, properties located within 0.4 kilometres of the nearest MRT station and transacted after the system began operating enjoyed a premium of approximately 12.4% (RM130,362 of the mean price), while properties located within the same distance from the nearest MRT station but sold during the construction of the MRT project generated a premium of only about 5.9% (RM62,028 of the mean price).

To fully understand the impact on prices before and after the MRT system began operating, a simple calculation can be performed. So, *ceteris paribus*, a fully operating MRT system generated a house price premium of approximately 6.5% which, at the mean, is RM68,335. However, properties located between 0.85 and 1.5 kilometres of the nearest MRT station and sold after the system began operating experienced a statistically significant decline in house prices of 7.9% which, at the mean, is RM83,053. Finally, *ceteris paribus*, for every metre decrease in distance to the One Utama shopping complex (1UTAMA) added 0.002% to house prices.

One of the important assumptions of the classical linear regression model (assumption five) is that the error terms have constant variance; i.e., they are homoscedastic. To determine the presence of heteroscedasticity in the model, the Breusch–Pagan test was performed (Breusch & Pagan, 1979). Table 3.39 shows the analysis of variance (ANOVA) results of the Breusch–Pagan test for heteroscedasticity. Those results show that the standard error of the estimate is highly significant ($p < 0.001$), which indicates the presence of heteroscedasticity in the model.

According to Gujrati and Porter (2009) and Breusch and Pagan (1979, p. 1287), the presence of heteroscedasticity can significantly affect the efficiency of OLS; more importantly, the biases in the estimated standard errors may lead to invalid conclusions. To improve the efficiency of the model due to the presence of heteroscedasticity, a WLS regression (Gujrati & Porter, 2009; Waddell et al., 1996) is used in the present study.

To correct for heteroscedasticity, Model 1 (Eq. 3) was run using WLS. The estimation was completed by running Model 1 using the weighted dependent and explanatory variables to minimize the sum-of-squared residuals (Tse & Love, 2000, p. 372):

$$S(\beta) = \sum w_t^2 (y_t - x_t^{\prime}\beta)^2 \tag{4}$$

where y_t is a general function of the explanatory variables x_t, and w_t is the value of the weight series.

Tables 4 shows the summary statistics of Model 1 which was run using WLS (Eq. 4), including a series of measures of fit such as the adjusted R^2, predictors, coefficients, standard errors, *t*-values, and indicators for the collinearity statistics tolerance and VIF. As Table 4 shows, the explanatory power of Model 1 increased from 0.818 to 0.865. Overall, the model results were close to the OLS for both estimated coefficients and positive and negative signs. It is worth noting that in OLS, the significant value on TREAT1 was at 0.1%, but in WLS the significance value increased to 0.05%. Another interesting observation from the model results is that two explanatory variables had lower estimated coefficients than when using OLS. For example, the coefficients on TREAT2 decreased slightly from 12.4% to 9.5%, and FREE decreased slightly from 18.5% to 17.4%.

5.0 Discussion

The present study adds to the growing literature on the impact of urban rail transit such as the SBK MRT Line on residential property prices. More importantly, the study provides valuable evidence on the relationship between access to urban rail transit stations and residential property prices in a rapidly growing city such as Greater Kuala Lumpur, Malaysia. Using a data set of nearly 600 residential properties and sales over a seven-year (2013–2019) period, the hedonic pricing model was developed and examined to better understand how the residential market responds to a major investment in public transportation. The longitudinal data used in this study allow measurement of before-and-after impacts of the MRT line, while the cross-sectional data enable an analysis of comparable properties across a geographic area.

The model results, after controlling for property markets with similar locational characteristics, income groups, and housing types, indicate a typical condominium unit located within 0.4 kilometres (the treatment zone) from the nearest MRT station and sold after the system began operating in the north-western portion of the city enjoyed a premium of approximately 9.5%, or RM99,874 over the city's mean home price, while a similar property located within the same distance from the nearest MRT station but sold before the system was operating (i.e., during construction) generated a premium of about 6%, or RM63,078, over the city's mean home price. The results of this study are consistent with research by Yang et al. (2020), Li (2018), Diao et al. (2017), Dubé et al. (2013), Duncan (2008), and Chen et al. (1998). A study conducted by Diao et al. (2017) in Singapore on the new MRT Circle Line, for example, found that the increase in house prices for properties located within 0.4 kilometres from the nearest station was about 13.2%. Based on the results of the present study, it can be concluded that there are two

E-ISSN: 2948-5231

stages of price increases. First, property prices are likely to increase during the construction phase of an MRT project. Second, when the system is fully operational, there will be another price increase, which will be greater than the first one.

Findings from this study have significance for the potential implementation of a land value capture policy as an alternative source of revenue to fund or partially fund urban rail transport in Greater Kuala Lumpur, which is totally neglected. Traditionally, it has been financed mainly through revenue sources such as user fees (ticket sales) and taxes, loans, bonds, public-private partnerships, and concessions (Lari et al., 2019). However, these traditional mechanisms are increasingly insufficient to finance the costs of construction, operation, and maintenance because transportation needs are complex and diverse. In addition, most urban rail systems are not self-sustaining; they require government subsidies to cover costs. At the same time, government financial support for public transportation is becoming more limited and uncertain. Given these challenges, it is critical to reflect on the implications of this study for the potential implementation of land value capture.

Table 3: Estimated model using OLS for condominium/service residence properties (n=594)

Variable	Unstandardized Coefficients		Standardized Coefficients		Collinearity Statistics	
	B	Std. Error	Beta	t	Tolerance	VIF
(Constant)	12.880	0.039		327.867***		
AREA	0.001	0.000	0.606	26.773***	0.577	1.734
FREE	0.185	0.021	0.239	8.948***	0.430	2.326
AGE	–0.028	0.002	–0.280	–12.233***	0.588	1.702
BED	0.033	0.021	0.037	1.533n/s	0.538	1.858
FLOOR1	–0.009	0.018	0.010	–0.520n/s	0.843	1.186
FLOOR2	0.013	0.019	0.013	0.687n/s	0.812	1.232
Y2019	0.336	0.035	0.294	9.720***	0.337	2.970
Y2018	0.328	0.032	0.320	10.207***	0.313	3.193
Y2017	0.311	0.030	0.322	10.207***	0.312	3.202
Y2016	0.275	0.029	0.237	9.368***	0.479	2.087
Y2015	0.258	0.028	0.253	9.291***	0.413	2.419
Y2014	0.164	0.027	0.165	6.139***	0.425	2.352
TREAT1	0.059	0.033	0.043	1.820*	0.549	1.822
TREAT2	0.124	0.032	0.107	3.910***	0.411	2.433
CTRL1	0.011	0.023	0.013	0.475n/s	0.430	2.323
CTRL2	–0.079	0.028	–0.075	–2.803***	0.431	2.319
1UTAMA	–2.3365E–5	0.000	–0.061	–3.122***	0.796	1.257

Notes: * and *** indicate significance at the 0.1 and 0.01 levels.

Table 4: Estimated model using WLS for condominium/service residence properties (n=594)

Variable	Unstandardized Coefficients		Standardized Coefficients		Collinearity Statistics	
	B	Std. Error	Beta	t	Tolerance	VIF
(Constant)	12.886	0.033		385.422***		
AREA	0.001	0.000	0.629	27.269***	0.440	2.274
FREE	0.174	0.010	0.272	9.421***	0.273	3.369
AGE	–0.032	0.002	–0.316	–15.430***	0.544	1.838
BED	0.020	0.017	0.025	1.153n/s	0.504	1.085
FLOOR1	0.009	0.015	0.010	0.604n/s	0.891	1.122
FLOOR2	0.003	0.016	0.003	0.190n/s	0.754	1.327
Y2019	0.338	0.033	0.255	10.186***	0.364	2.745
Y2018	0.334	0.030	0.310	11.230***	0.298	3.351
Y2017	0.321	0.029	0.299	11.089***	0.313	3.194
Y2016	0.292	0.024	0.370	12.064***	0.242	4.128
Y2015	0.255	0.023	0.301	10.423***	0.272	3.674
Y2014	0.166	0.022	0.246	7.446***	0.209	4.777
TREAT1	0.060	0.025	0.059	2.383**	0.367	2.727
TREAT2	0.095	0.030	0.076	3.191***	0.403	2.479
CTRL1	0.002	0.020	0.003	0.128n/s	0.331	3.023
CTRL2	–0.069	0.029	–0.061	–2.405**	0.350	2.860
1UTAMA	–2.319E–5	0.000	–0.072	–4.040***	0.710	1.409

Notes: ** and *** indicate significance at the 0.05 and 0.01 levels.

As noted above, the results of this study suggest that the price premium for housing near the MRT station was 9.5%. Since this price premium results from public investment, it is reasonable for public authorities to seek to capture this surplus. Thus, we may illustrate land value capture under different mechanisms scenarios for Greater Kuala Lumpur. One method is to impose a direct value capture tax assessment within the urban rail transit development's expected catchment area. Using the data based on 594 transaction records for condominium units located within 0.4 kilometres of the nearest MRT, the average price, the price premium created by MRT, and divided by the average size of the property, with the value increment calculated in Malaysian ringgit.

Table 5 shows the results of value increments accruing from SBK MRT Line access. The table shows that the value increment amounts to nearly RM17 million. Introducing an urban rail transit value increment tax of 0.5%, 1%, and 5% on condominium/service residence units would produce revenues of over RM84,000, RM168,000 and RM840,000, respectively. These figures are only indicative of the value capture revenue estimated from transaction records of condominium units obtained for this study. An interesting accounting implication based on this value capture revenue is that it could be a significant financial incentive to at least partly fund urban rail transit projects in Greater Kuala Lumpur.

E-ISSN: 2948-5231

Table 5: Estimation of value increment from MRT access

Radius distance	Property area (sq. feet)	Price premium	Value increment (Ringgit Malaysia)
Radius 0.4 km	212,645	0.095	16,831,750.82
	Simulation of value capture scenarios		
	0.5% capture rate		84,158.75
	1.0% capture rate		168,317.51
	5.0% capture rate		841,587.54

Notes: Property refers to floor area of condominium/service residence units. Value increment is a result of property units*average price*price premium/average floor size of building. Average prices and average buildings are RM1,527,260 and 1,833, respectively.
Source: Adapted from Xu et al. (2016).

6.0 Conclusions

This study used a hedonic pricing model with transaction-based data to estimate the impacts of the SBK MRT Line on residential property prices in Greater Kuala Lumpur, Malaysia. To accurately estimate those impacts, a sample of condominium/service residence units was analysed by similar locational characteristics and income groups assumed to have homogeneous tastes, and by similar housing types. The results show that a typical condominium/service residence unit located within 0.4 kilometres of the nearest MRT station is highly valued by homebuyers. More specifically, a typical condominium/service residence unit located within 0.4 kilometres of the nearest MRT station and transacted after the system began operating enjoyed a premium of approximately 9.5% (RM99,794.68 of the mean price), while properties located within the same distance from the nearest MRT station but sold during the construction of the MRT project generated a premium of only about 6% (RM63,028.22 of the mean price). The study has indeed contributed to the literature by showing the premium associated with rail accessibility in Greater Kuala Lumpur, Malaysia.

Although the results of this study are considered relatively robust, there are some limitations that should be considered in tandem with avenues for future research. Hence, future research should use longer periods of longitudinal data that begin at least five years before the announcement of the construction of a new MRT line in the area. Future research is also suggested to estimate both residential and commercial properties and, if transaction records permit, comparative estimation based on individual stations should be carried out.

Acknowledgement: The author would like to thank the National Real Estate Research Coordinator (NAPREC), National Institute of Valuation (INSPEN) and the Ministry of Finance, Malaysia for funding this project.

Conflicts of Interest: The author declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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E-ISSN: 2948-5231