Spatial Analysis of the Relationship between Residential Property Value and Accessibility in Jakarta

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Abstract: The values of residential property are different across spatial area and building types in accordance with structural condition, access to transportation stations and proximity to public facilities. Ordinary least square (OLS) shows a global relation but is unable to capture local differences. Geographic weighted regression (GWR) reveals this shortage by considering local variety in a particular area. This study aims to explore the relationship between residential property value with structural, accessibility and neighborhood attributes in Jakarta by utilizing GWR. The results reveal that different residential buildings have different significant factors in different areas. Public transportation facilities (e.g. BRT Station and Commuter Line Station) do not affect property price even though they have already been established. Property price is affected by geographic location accessibility to street, and public places such as the CBD area.

Keywords: Property Value Appreciation, Transit Oriented Development, Hedonic Price Model, Geographic Weighted Regression, Urbanization, Residential Area.

1. INTRODUCTION

Nowadays, urbanization is occurring around the world, particularly in the cities of developing countries. It is caused by rapid economic such as industrial, business, trade, residential and some agricultural activities, which makes activity within the city more diverse. Different activities generate changes in the physical conditions including land use, street layout, geographic appearance, infrastructure, and building composition (Firman, 2009).

In addition, urbanization is also in line with population increase and housing availability. The downtown area provides many advantages such as high accessibility and services, which makes housing prices in this area relatively more expensive than those in the outskirts and causes housing speculation in some areas (United Nations, 2016). Usually only high-income earners are able to purchase houses or rent apartments in the city centers, while most people usually live in the outskirts of the city and commute to their workplaces. Commuting can be a good way to balance costs (e.g., time and housing) if supporting infrastructures are well established, however if the supporting infrastructures are currently not available, it will cause many problems such as congestion, pollution, and traffic accident.

Jakarta, the capital city of Indonesia, is experiencing rapid urbanization. Thirty years ago, the population of Jakarta was 6.5 million and this had risen to 9.6 million in 2010 (DKI Jakarta Statistic Bureau, 2018). Some residents avoid living in the downtown area and force to commute. Unfortunately, Jakarta has some of the worst traffic congestion in the world (DKI Jakarta Statistic Bureau, 2018). Around US$3 billion has been spent on tackling the effects of traffic congestion. Even though BRT Transjakarta and Commuter Train had been developed, private vehicle ownership is still high, almost 83% of people own private cars (United Nations, 2016) and those who lived in the outskirts of Jakarta prefer to use their own vehicle, which can reduce transportation costs by 30% (Rukmana, 2018).

To address these problems, the DKI Jakarta Provincial Government have established many transportation infrastructures in Jakarta. BRT Transjakarta routes have been established in almost all areas of Jakarta, a light rapid transit (LRT) route from Kelapa Gading to Veldromore opened in July 2018 and mass rapid transit (MRT) Line has been under construction since 2013. By 2024, DKI Jakarta Government will have opened 21 MRT stations and that can accommodate 1.5 million passengers per day. MRT phase 1 (Lebak Bulus-Hotel Indonesia) which will be able to transport 1,200 passengers per trip by using the maximum of six carriages per train, and will be operated in 2019 (Rukmana, 2018).

Furthermore, to address transportation problems in Jakarta, the DKI Jakarta Provincial Government plans to develop transit-oriented development (TOD) as a sustainable transportation policy (Hasibuan *et al.* 2014). TOD is a concept that provides walkable, mixed use forms of development focused around a transit station; concentrating higher density development near stations makes transit convenient and encourages ridership (Center for Transit Oriented Development, 2004). TOD can create land and property values increase. It should be used to create and preserve affordable area, specifically affordable housing near transit. The analysis of property value is needed to help decision maker specifically government in regulating property value around TOD point to achieve affordability purpose of TOD construction.

Many studies have been conducted on property value and transportation (Dubé, *et al.* 2013; Mohammad *et al*. 2013; Geng *et al.* 2015; Seo *et al*. 2014; Yen *et al.* 2018), specifically in developed countries. There is a lack of preview studies on cities in developing countries due to lack of data availability, however nowadays the analysis of property value is an important area of studies in developing countries, such as Indonesia, to address the negative impact of urbanization.

This study attempts to fill the gap in the socio-economic analysis in terms of residential property values and transportation in Jakarta. The objectives of this study are as follow: 1) Determine the significant factors regarding residential property values and 2) explore the relationship between residential property values and transportation also other facilities. The analysis considers house and apartment values separately and attempts to reveal the relationship with structural condition, access to transportation nodes, and proximity to facilities in different areas of Jakarta. By analyzing how is the relationship between accessibility and residential property value, it can be known which factors that can improve the condition of property near transit. When the property become better, it can attract people to live near transit for reducing transportation cost and achieving sustainable transportation.

2. LITERATURE REVIEW

The relationships between transportation and property value, specifically residential property value, vary across different areas and property types. Property segmentation, transportation mode type, and various other attributes can affect these relationships (Bohman and Nilsson, 2016). Public transport infrastructure can result in two different impacts: positive externalities due to the increase in accessibility to many places and negative externalities related to pollution, traffic accidents and criminality (Dubé, *et al.* 2013). Distance from a station will generate a combination of different positive and negative impacts (Mohammad *et al*. 2013;

Geng *et al.* 2015). Proximity to improved transport infrastructure and network will lead to a greater improvement in accessibility than in other areas (Boarnet, 2007). Seo *et al*. (2014) also argue that negative impact around transport nodes is relatively small and decrease as distance from the node increase. At the same time, the positive impact from being located near a station is relatively high and declines as distance from the station increases. However, Mulley *et al*. (2016) reported that proximity to a train station in Brisbane, Australia has a significant negative impact due to the proximity of the station to the CBD area; positive impact cannot balance the disadvantages of of activity in the CBD area.

Different modes of public transportation also result in different impacts on property value. A regional commuter line station is predicted to have a strong impact on increasing property prices in South Scania, Sweden (Bohman & Nilsson, 2016) specifically for labor or low-income earners. For high-income earners, public transportation mode does not matter when deciding residential location due to high preference for using private vehicle. In line with this, Debrezion, *et al*. (2007) and Mohammad *et al.* (2013) also found that heavy rail and metro show greater impact than light rail. This may be because heavy rail has a higher environmental impact than light rail and commuter lines can provide more beneficial access to travelers over a longer distance than light rail, which is more relevant for shorter distances. On the other hand, BRT also have a significant impact on property price increases in Brisbane, although this in only 0.14% for every 100 meters from a BRT Station (Yen *et al*. 2018).

Different property types may experience varied impacts from public transportation modes. Most studies found that public transport, specifically railway stations, can increase commercial property value more than residential property value due to economic benefit. However, Debrezion *et al.* (2007) revealed the impact of proximity to railway station on residential property is greater than commercial property.

3. AREA OF STUDY

According to DKI Jakarta Statistic Bureau (2018), total area of Jakarta is 662.33 km^2, which is occupied by 10,374,235 inhabitants with a population growth rate of 0.94 % per year. The highest population density is in West Jakarta with 19,516 people/km^2. An increase in economic activity effects population rate, different activities (industrial, business, trade, residential and some agricultural activities), urban form, and transportation conditions. The metropolitan area of Jakarta has the highest levels of economic development (Rukmana, 2018). It generates high commuting activity from inside or outside Jakarta. Millions of people commute daily within Jakarta City and the adjacent areas, including Kabupatens (District) and Kotas (Municipality) of Bogor, Tangerang, and Bekasi either by bus, trains, or private cars (Firman, 2009).

Regarding transit stations, the characteristic of transit stations in Jakarta is mostly moderate mixed-land use form. Some areas near transit stations are occupied by 30-40% residential and commercial space but the compactness is not so high near transit stations. It means that there are more houses or working space are located far from the station. It shows that Jakarta's land use is still characterized by urban sprawl and people still use road-based transport (private or public vehicle) to travel instead of railway-based transport modes. Other factors such as non-motorized transportation (walking, cycling, on foot), specifically near station, are still low (Hasibuan *et al*. 2014).

The Jakarta government plans to develop TOD areas to increase accessibility and sustainable transportation. A TOD area is a mix of residential and commercial developments with high accessibility to public transportation. The station itself is the central area with high building density (DKI Jakarta Governor Decree No. 44, 2017). There are six areas, which are mentioned in DKI Jakarta Local Decree No. 1, 2012 consisting of two TOD in the primary central area (TOD Dukuh Atas and TOD Manggarai) and four TOD in a secondary central area (TOD Grogol, TOD Harmoni, TOD Senen and TOD Blok M). In more detail, the Greater Jakarta Transport Authority (BPTJ) plans to develop 34 urban TOD in Greater Jakarta, which will be divided into three phases as showed in Table 1. Phase 1 will be completed in 2019, phase 2 will continue until 2024, and phase 3 until 2030 (BPTJ, 2019).

Table 1. Urban TOD in Jabodetabek

PHASE 1	**PHASE 2**	**PHASE 3**
1. TOD Dukuh Atas*	17. TOD Tangerang Stasiun	31. TOD Cibinong
2. TOD Ploris Plawad	18. TOD Rawa Buaya*	32. TOD Cinere
3. TOD Tanah Abang*	19. TOD Jakarta Kota*	33. TOD Cikarang Jababeka
4. TOD Bekasi Timur / Jati Mulya	20. TOD Cawang Cikoko*	34. TOD Tanjung Barat*
5. TOD Bekasi Barat	21. TOD Depok Baru	
6. TOD Pondok Cina	22. TOD Tanjung Priok*	
7. TOD Gunung Putri	23. TOD Grogol*	
8. TOD Bogor	24. TOD Manggarai*	
9. TOD Kampung Rambutan*	25. TOD Jati Jajar	
10. TOD Cisauk	26. TOD Cibubur*	
11. TOD Blok M*	27. TOD Pasar Senen*	
12. TOD Lebak Bulus*	28. TOD Sentul	
13. TOD Juanda*	29. TOD Jati Cempaka	
14. TOD Rawa Buntu	30. TOD Pancoran*	
15. TOD Jurangmangu		
16. TOD Baranangsiang		
*) Urban TOD in DKI Jakarta Province		

Source: Greater Jakarta Transport Authority (BPTJ), 2018.

Intensive development of economic activities over the last 30 years has caused huge land conversion from agricultural to nonagricultural land. Existing residential areas have also developed into new forms such as mixed-function areas including offices, entertainment, and business space. One example is Sudirman CBD. Speculation often occurs in most land conversions conducted by private sector developers (Firman, 2009). High economic activity in Jakarta encourages many people from other cities and islands to come and live in Jakarta, which increase the need for housing. Figure 1 represents Jakarta's house needs in 2015. Compared to other provinces in Indonesia, Jakarta has the second highest housing demand. Around 1.27 million affordable houses should be constructed to meet all demands (DKI Jakarta Statistic Bureau, 2018).

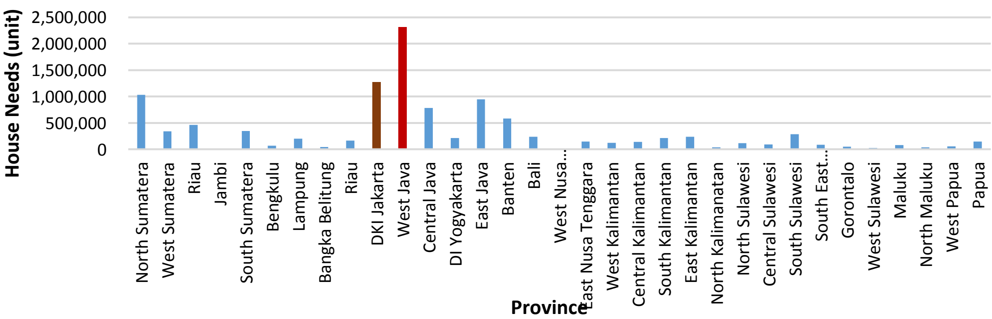


Figure 1. House Needs in Jakarta in 2015

Source: DKI Jakarta Statistic Bureau, 2018.

4. METHODOLOGY AND DATA

This study uses a hedonic price model (HPM). This model uses ordinary least square (OLS) to estimate the effects of various housing attributes on property price. Variables are categorized according to structural, neighborhood and transportation attributes. The general equation for housing price based on structural (S), transportation (T) and neighborhood attributes (N) is described in Equation 1 below

$$P = f(S, T, N) \tag{1}$$

where

P = Property price
S = Structural Attributes
T = Transportation Attributes
N = Neighborhood Attributes

An HPM can usually be applied in developed countries because they have complete databases, which enables thorough analysis. However, there are some data limitation in developing country, so there are fewer independent variables that in developed countries (Sharma & Newman, 2018). The OLS method assumes that the dependent variable has a homogeneous response to independent variables across geographic location, which is measured by fixed coefficients for all the observations (see Equation 2). The traditional OLS method belongs to a global parameter estimation, and cannot capture local difference (Xu *et al.* 2017).

$$P = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \; \ldots\ldots \; + \beta_n x_n + \varepsilon \tag{2}$$

where

P = Property price
β = coefficients
x = independent variables
ε = Random error term/residuals

To cover main limitation of OLS, Moran’s I will be applied to examine the spatio-temporal effect in the model. Spatial effect cannot be ignored in the case of Jakarta due to diverse spatial and local characteristics. Moran's I is used to examine whether there is a spatial autocorrelation in regional economic variables. The equation for Moran’s I is defined in Equation 3 (Huang *et al*. 2018)

$$I = \frac{n}{\sum_{i=1}^{n}\sum_{j=1}^{n} w_{ij}} \times \frac{\sum_{i=1}^{n}\sum_{j=1}^{n} w_{ij}\,(x_i - \bar{X})(x_j - \bar{X})}{\sum_{i=1}^{n}(x_i - \bar{X})^2} \tag{3}$$

where

I = Moran’s Index
n =sample size
x_i= housing price in *i* location
x_j = housing price in specified area
$\bar{X}$= mean of the attribute
w_{ij} = spatial weight matrix

The aim of GWR is to address the issue of spatial non-stationarity directly and allow the relationships we are measuring to vary over space. The main output from GWR is a set of location-specific parameter estimates, which can be mapped and analyzed to provide information on spatial non-stationarity in relationships. GWR (Equation 4) is effective to detect the spatial-nonstationary process, however, the multi-collinearity will become very severe when working with small samples.

$$y_i = \sum_{j=0}^{j=n} \beta_{ij} * x_{ij} + \varepsilon_i \tag{4}$$

where

y_i = dependent variable for location i

x_{ij} = independent variables

ε_i = error term, which should be independently and normally distributed

This study uses ArcGIS 10.2 software to run all of processes. This method is according to analysis procedures process from the ArcGIS tutorial (Bennett, 2012). These methods are chosen as initial analysis of the relationship between property value and transportation facilities and various conditions in Jakarta. Furthermore, the regression analysis process also followed hedonic analysis of housing prices in Shanghai from (Huang *et al.* 2017).

This study uses 24 explanatory variables categorized into three groups: structural, transportation and neighborhood variables. The variables are selected following various studies (Xu *et al.* 2017; Sharma and Newman, 2018; Huang *et al.* 2017) regarding residential property value evaluation. Flood prevention and other variables related to new public transportation such as TOD in commuter line stations and BRT stations are also considered. Spatial or location variables such as property location in South, North, West and Central Jakarta are also analyzed. In this case, East Jakarta is set as the baseline area for comparing property prices among five areas. Table 2 presents descriptive analysis of house and apartment attributes.

Table 2. Descriptive Analysis of House and Apartment Attributes

No	Variables	Mean	Min.	Max.	St. Dev.	Mean	Min.	Max.	St. Dev.
		House				Apartment			
1	Price	2048.857	101.297	8722.222	1552.443	2022.648	14.578	4329	863.950
2	B_Area	399.306	48	1800	310.025	89.228	18	600	82.296
3	Facility	1.670	1	3	0.858	1.822	1	3	1.094
4	Design	0.770	0	1	0.422				
5	Flood	0.743	0	1	0.437	Not considered			
6	Parking	0.924	0	1	0.265				
7	Pop_Dens	157.504	74.348	481.737	48.330	164.480	74.348	55.720	55.720
8	D_Mall	1358.589	46.380	3682.827	877.100	1010.774	17.276	651.924	651.924
9	D_TM	1190.910	1.273	4495.603	814.829	994.311	94.940	673.758	673.758
10	D_HP	1098.665	13.857	4339.883	713.742	975.566	59.676	554.158	554.159
11	D_SC	389.738	1.365	1285.512	280.147	395.394	11.571	267.525	267.525
12	D_CBD	5985.691	1	14122.710	3657.340	3036.122	1	3376.394	3376.394
13	D_1st	5440.132	283.857	11488.800	2590.292	2577.637	176.733	1835.053	1835.053
14	North	0.131	0	1	0.338	0.114	0	0.318	0.318
15	West	0.238	0	1	0.427	0.202	0	0.402	0.402
16	South	0.537	0	1	0.500	0.465	0	0.499	0.500
17	Center	0.034	0	1	0.182	0.211	0	0.408	0.408
18	East	Baseline area							
19	D_CS	2924.433	103.374	6794.239	1729.917	1973.041	248.517	1201.625	1201.625
20	D_HW	1525.967	76.698	3723.750	936.233	1539.496	68.508	1052.741	1052.741
21	D_TollExit	1692.162	58.187	3843.269	864.482	1723.108	137.554	936.947	936.947
22	D_AR	684.295	4.568	3042.502	592.792	659.991	9.587	506.484	506.484
23	D_COL	135.092	0.135	511.817	108.385	139.354	1.835	134.6300	134.630
24	D_BRT	1431.381	58.945	5260.685	1154.480	879.432	81.966	721.908	721.908

No Variables	Mean	Min.	Max.	St. Dev.	Mean	Min.	Max.	St. Dev.
	House				Apartment			
25 TODCS	733.929	0	6748	1676.812	562.591	0	975.338	975.338
26 TODBRT	69.526	0	1995	307.045	45.790	0	230.409	230.409

Structural variables are related to the physical appearance of a building such as total area, design, furniture and parking space availability. The structural data are collected from property agency who provide information about houses, apartments, offices, or retail buildings for selling, buying or renting. The price information is the listed price not the transaction price. After the transaction process is complete, the final price may be the same or up to 20% lower than the listed prices, based on building location and level of competition. Transportation variables relate to accessibility to transportation facilities such as streets, bus and train stations and TOD station along bus and commuter train stations. Only 16 TOD are considered in this study, 11 in train stations and five in bus stations. Neighborhood variables relate to accessibility to public facilities such as schools, hospital, and department stores as well as spatial location and population density. Transportation and neighborhood variables are collected from DKI Jakarta Government departments such as the Ministry of Public Works and Housing, the Ministry of Education and the Ministry of Economy. The variables are presented in Table 3.

Table 3. Description of Variable (Data in 2018)

No	Variable	Type	Code	UNIT/SCALE	Expected Sign
1	Property Price	Dependent Variable	Price	USD/m^2	
2	Building Area	Structural	B_Area	meter^2	+
3	Facility		Facility	fully furnished/semi furnished/unfurnished	+
4	Design		Design	LOCAL/MODERN	+
5	Parking		Parking	YES/NO	+
6	Flood Prevention		Flood_Pr	YES/NO	+
7	Population Density	Neighborhood	Pop_Dens	People/ha	-
8	Distance to Mall		D_Mall	Meter	-
9	Distance to Traditional Market		D_TM	Meter	-
10	Distance to Hospital		D_HP	Meter	-
11	Distance to School		D_SC	Meter	-
12	Distance to CBD		D_CBD	Meter	-
13	Distance to Primary Central Area		D_1st	Meter	+ or -
14	Property in North Jakarta		North	0 / 1	+ or -
15	Property in West Jakarta		West	0 / 1	+ or -
16	Property in South Jakarta		South	0 / 1	+ or -
17	Property in Center Jakarta		Center	0 / 1	+ or -
18	Property in East Jakarta			Baseline Area	
19	Distance to Commuter Line Station	Transportation	D_CS	Meter	-
20	Distance to Highway		D_HW	Meter	-
21	Distance to Toll Exit Gate		D_TollExit	Meter	-
22	Distance to Arterial Road		D_AR	Meter	-
23	Distance to Collector Road		D_COL	Meter	-
24	Distance to BRT		D_BRT	Meter	-
25	TOD in Commuter Line Station		TODCS	0 / 1	-
26	TOD in BRT Station		TODBRT	0 / 1	-

This study analyzed two types of residential building, house and apartments, separately because each has very different characteristics. A total of 724 residential property samples were collected, comprised of 382 houses and 342 apartments. Houses are a common residential type for Indonesian citizens, one building is generally owned by one family and only built for one purpose (residential). Apartments are modern high-rise residential buildings and are usually located in big cities or metropolitan areas.

5. ANALYSIS AND RESULT

Neighborhood and accessibility attributes are found to have more effect in the case of both houses and apartments. Structural attributes only affect housing price in terms of flood prevention. Tables 4 and 5 show a summary of OLS output for houses and apartments.

Table 4. Summary of Ordinary Least Square (OLS) (House)

No	Variable	Coefficient	T-Value	
0	Intercept	3295.07	5.03	***
1	B_Area	0.26	1.07	
2	Facility	128.07	1.56	
3	Design	-84.82	-0.45	
4	Parking_Pr	51.46	0.19	
5	Flood	-353.31	-2.00	**
6	Pop_Dens	-6.84	-3.55	***
7	D_Mall	0.053	0.53	
8	D_Traditional Market	-0.01	-0.06	
9	D_Hospital	-0.19	-1.62	
10	D_School	0.90	2.97	***
11	D_CBD	-0.01	-0.28	
12	D_Primary Area	-0.21	-4.85	***
13	North Area	499.50	1.31	
14	West Area	744.12	2.03	**
15	South Area	1804.24	4.98	***
16	Center Area	1674.11	3.38	***
17	East Area	Baseline Area		
18	D_Highway	0.32	1.87	***
19	D_TollExit Gate	-0.47	-2.56	**
20	D_Arterial Road	-0.23	-1.73	*
21	D_Collector Road	-2.21	-3.38	***
22	D_BRT Station	-0.09	-0.93	
23	D_Commuter Line Station	0.14	2.21	**
24	TODCS	-0.02	-0.45	
25	TODBRT	0.25	0.97	

Note: ***, **, and * represent 1% , 5% , and 10% levels, respectively. The sample size is 382.
R^2 = 0.37. AdjR^2= 0.33

Adjusted R-squared is 0.33 for houses, meaning 33% of the variance can be explained by independent variables in the model, and 0.43 (43% variance) for apartments. The coefficient of each variable reveals the relationship between property prices and independent variables. A negative sign of coefficient indicates that an independent variable has negative correlation to property price as the variable increase. In contrast, a positive sign indicates a positive relationship with property price as the variable decrease.

In the case of houses, distance to primary school, commuter line and highway have a positive sign, which indicates that houses prices decrease with proximity to these features. Regarding primary schools, the area surrounding a school may be noise and crowded.

Regarding commuter line station and highway, the areas around these are usually associated with slums bad environmental quality such as noise, pollution, and congestion. The areas around commuter line stations are not well designed or integrated with many facilities (Rukmana, 2018).

The flood prevention variable shows a negative sign, which is unexpected. It should show a positive sign, which would indicate the property is at less risk of flooding and the price would be expected to increase; however, this is not the case. This may be because the judgment of this variable is based on location only without considering the physical condition of the property.

Residents of Jakarta still have high dependence on private vehicles rather than using trains or buses. Private motorcycles account for 53% of privately owned vehicles in Jakarta and private cars account for 20%. Public transportation modes account for only 27% of all modes (Prayudyanto, 2017). The data prove that most people in Jakarta use private vehicles rather than public transport. Proximity to major roads (Arterial Road, Collector Road and Toll Exit Gate) is an important consideration. It is become the reason behind the negative sign of distance to those attributes.

However, there is no significant correlation with other public transport locations (BRT Station and TOD Area). Regarding BRT Station, house prices are expected to be higher in areas close to BRT line (Transjakarta Bus) because these lines have excellent access to other parts of the cities. However, the results imply BRT Stations have no impact on property price.

Regarding TOD Area, these areas are still in the development process, but some areas have already been designated as TOD areas based on the complexity of location, high accessibility, and high development potential. Property price may start to increase once a project is announced. However, the results indicate that TOD in Jakarta do not affect property prices in the beginning of 2018 because they have not been implemented completely. MRT and LRT lines are under construction are not yet integrated with other activities that will be provided inside TOD areas.

In 2017, some stations in Jakarta metropolitan area started to implement the TOD concept. For example, a new apartment building was constructed near Pondok Cina Station, which is located in Depok City. Because it had already been announced that there would be a TOD Area in this station, the apartments sold out very quickly. There are plans to construct other TOD areas in well developed areas, the land and the property prices in these areas have already increase, such as in Sudirman/Dukuh Atas Station. Therefore, property is expensive not because of new development of public transport but due to earlier development increasing property prices. This study was conducted in early 2018, the impact of TOD areas is not obvious for all area in Jakarta. The impact of integrated public transportation infrastructure is not likely to be visible for another five to seven years.

Population density is one of the significant variables with negative sign indicating that high density can lower house prices. Housing in Indonesia is commonly high density, which results in limited vacant land. High population in developing countries and cities, specifically in Jakarta, combined with disorganized development can exacerbate many problems such as lack of fresh water and green open spaces, and high levels of criminal activity. All municipality/district variables, all variables show positive signs. The highest coefficient is South Jakarta indicating this area has the highest prices among five districts in Jakarta.

In the case of apartment, distance to CBD, Collector Road, Highway, and population density are negatively correlated. Most apartments are located near CBD to support high activity and their increase as distance to the CBD area becomes shorter. Distance to collector road and highway shows a negative sign, indicating that people still use their own vehicle for commuting. In line with this, distance to toll exit gate become a significant variable but has a positive sign because the worst congestion always occurs. Table 5 presents the OLS results for apartments.

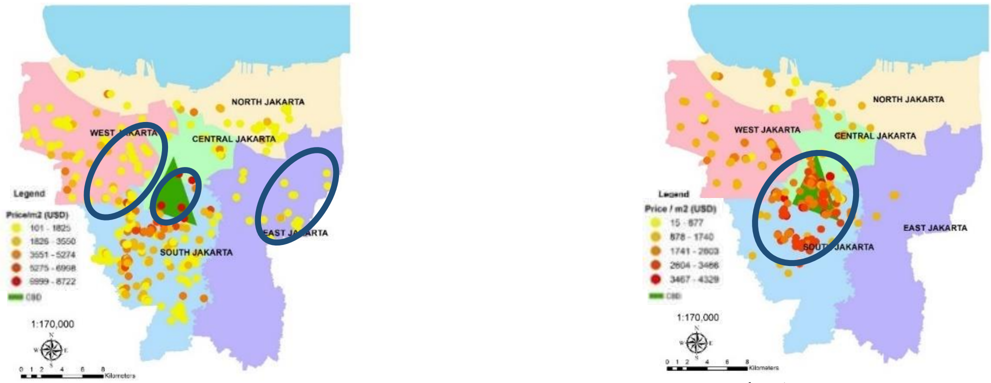
Other variables also show positive sign (distance to department store, hospital, primary central area, and commuter line station). This indicates that these facilities are important, but it is better to be farther away from these to avoid disamenities such as air pollution, noise, congestion, crime and other negative impacts. All municipality/district variables show positive signs. The highest coefficient is for West Jakarta, indicating that property prices are highest here among the five districts in Jakarta.

Table 5. Summary of Ordinary Least Square (OLS) (Apartment)

No	Variable	Coefficient	T-Value
0	Intercept	1110.96	2.07 **
1	B_Area	0.58	1.20
2	Facility	29.30	0.88
3	Design		
4	Parking Pr	Not considered	
5	Flood		
6	Pop_Dens	-2.64	-2.91 ***
7	D_Mall	0.19	2.46 **
8	D_Traditional Market	-0.02	-0.19
9	D_Hospital	0.31	2.73 ***
10	D_School	0.08	0.48
11	D_CBD	-0.21	-7.31 ***
12	D_Primary Area	0.09	2.70 ***
13	North Area	470.95	1.030
14	West Area	1056.13	2.46 **
15	South Area	651.90	1.51
16	Center Area	535.18	1.26
17	East Area	Baseline Area	
18	D_Highway	-0.30	-2.03 **
19	D_TollExit Gate	0.54	3.57 ***
20	D_Arterial Road	-0.23	-1.69 *
21	D_Collector Road	-0.81	-2.24 **
22	D_BRT Station	0.04	0.44
23	D_Commuter Line Station	0.11	1.90 *
24	CSTOD	-0.02	-0.41
25	BRTTOD	0.04	0.21

Note: *** , ** and * represent 1% , 5% , and 10% levels respectively. The sample size is 342. $R^2 = 0.46$. Adj$R^2 = 0.43$

OLS outputs are generally the same for all of the mentioned variables. This cannot explain which areas are more affected by facilities that will generate high property prices. To ascertain this, GWR can used but spatial autocorrelation test should be conducted first to determine if there is any spatial dependency.



a. House b. Apartment

Figure 2. Property Price Distribution

Moran's I is positive for both houses (0.121) and apartments (0.286), indicating that, in geospatial distribution, property values of similar properties tend to cluster in one area. This is also confirmed by positive Z-Scores (4.012 and 10.39, respectively) indicating that there is a positive spatial autocorrelation and similar properties with the same price are clustered in certain areas. Figure 2a reveals that the majority of cheaper houses are located in the same areas, such as in East, West and North Jakarta, while expensive houses are located near the CBD area. On the other hand, the majority of high-price apartments are located near the CBD Area and in South Jakarta (see Figure 2b). The CBD area provides many advantages, specifically regarding high access to economic activities. Office or workplace activities are the main activities in the CBD area, which is surrounded by a growing commercial area that includes restaurants, department stores, hotels, and amusement parks.

Table 6. R^2 in OLS and GWR

Case	OLS	GWR
House	$R^2 = 0.37$	$R^2 = 0.34$
	$AdjR^2 = 0.33$	$AdjR^2 = 0.31$
Apartment	$R^2 = 0.46$	$R^2 = 0.45$
	$AdjR^2 = 0.43$	$AdjR^2 = 0.41$

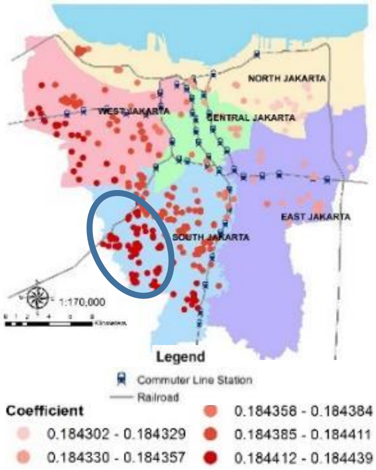
Spatio-temporal analysis using Moran's I confirms that spatial dependence exists in both cases; the OLS results do not apply to all areas. Theoretically, the R-squared of GWR should be higher than that of OLS. This study revealed that both cases do not show an increase in R-squared (see Table 6), which may be because GWR has limitation regarding small size sample and binary variable. GWR can identify direction and strength of influences from the same independent variables. It can be interpreted by examining the distribution of coefficients in each variable. For variables with positive signs, smaller coefficients indicate less impact on increasing property price. Meanwhile, for variables with negative signs, smaller absolute coefficients indicate greater impact on increasing price.

Transportation infrastructure attributes with positive signs are distance to commuter line station and highway variables (see Figure 3a and Figure 3b). There is only a slight difference observed in the R-squared of each variable between the strongest and the weakest relationship. The strongest effect is shown in west of South Jakarta. This may be because the commuter line seems less desirable for commuting. The station environment may not be particularly good and people therefore tend to use private cars or buses (roadway based) to access other areas. There is an outer ring road in South Jakarta, which connects Jakarta with other provinces. Many cars or trucks use this route to access the port or airport in west of Jakarta Province and the pollution and congestion may therefore be higher than in other areas.

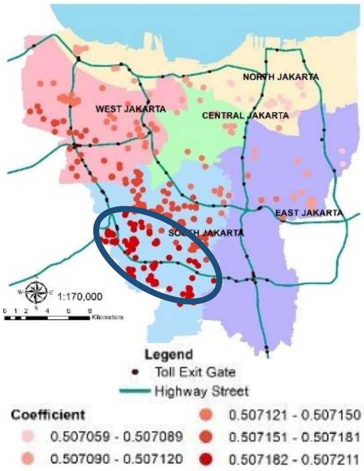
High dependence on private vehicles in Jakarta can be proved by many street variables (Collector Road, Arterial Road, Highway, and Toll Exit Gate) that have greater effect on property price compared to public transportation. Housing prices in South Jakarta are highly effected by proximity to collector roads (see Figure 3c). This may be because there are not so many commuter line stations as in Central or South Jakarta. In East and North Jakarta, BRT line connect to some collector roads, which makes people in this area more willing to pay for houses with short distance from collector road. Distance to arterial road also has a negative sign in West and South Jakarta (see Figure 3d). Distance to toll exit gate has a strong relationship with housing price in South and East Jakarta (see Figure 3e).

In the case of apartments, distance to toll exit gate shows positive sign. Central Jakarta is the area with the strongest effect (see Figure 4a). This may be because this area has high population and building density, meaning that negative impacts on nearby streets are relatively high compared to other areas. The highway (inner ring road) in this area is one of the primary highways for entering Jakarta. Hence, congestion levels will be the worst and pollution levels cannot be ignored (see Figure 5c).

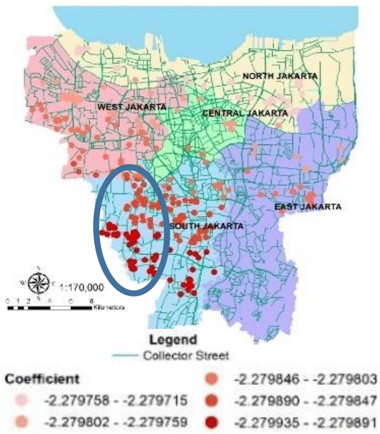
Distance to collector road shows a negative sign. The strongest coefficient of distance to collector road is found in Central Jakarta (see Figure 5b); the most expensive apartments are located there because it is close to the CBD area. It also includes government offices, public facilities and other economic activities that are located close to such roads. In contrast, distance to commuter line station has a positive sign in close to the CBD area indicating more expensive apartments are located far from station to avoid negative impacts. It also reveals that the residents are more using private vehicle than commuter line (see Figure 5d).



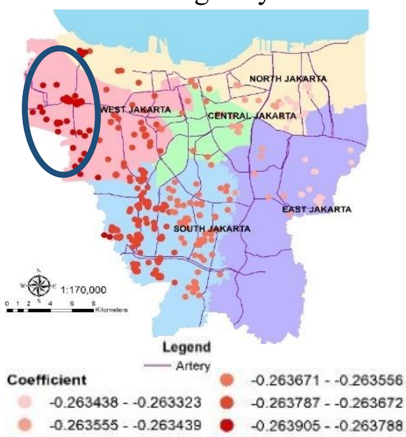
a. Commuter Line Station



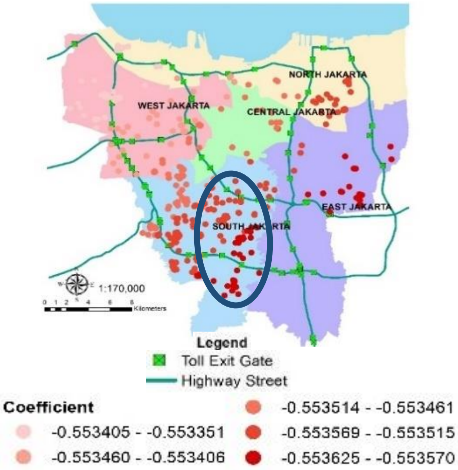
b. Highway



c. Collector Road

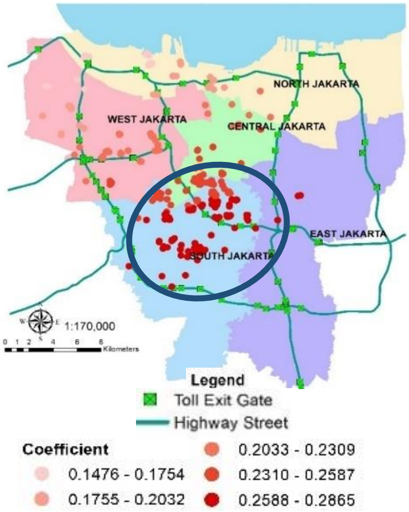


d. Arterial Road

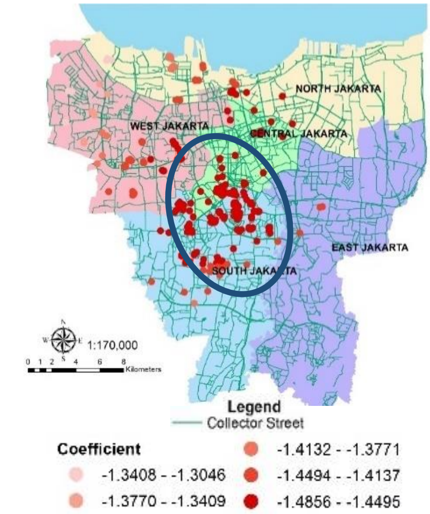


e. Toll Exit Gate

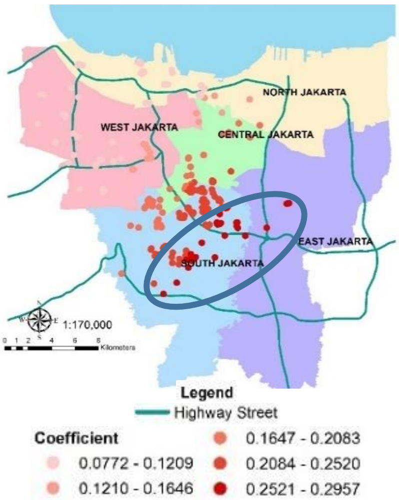
Figure 3. Transportation Infrastructure Coefficient Distribution (House)



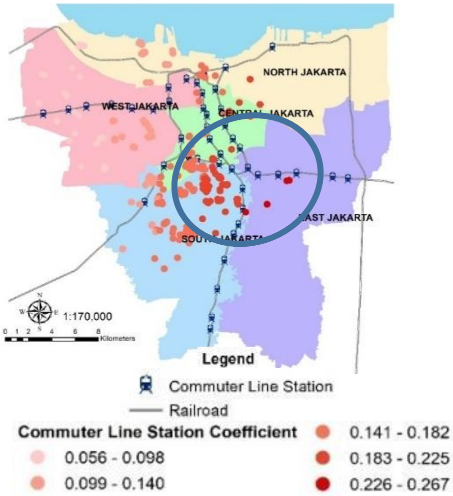
a. Toll Exit Gate



b. Collector Road



c. Highway



d. Commuter Line Station

Figure 4. Transportation Infrastructure Coefficient Distribution (Apartment)

6. CONCLUSION

Understanding relationships between property values and transportation aspects is very important as one of requirements to improve transportation and housing conditions in Jakarta. This study determined significant factor of property value in Jakarta. The relationship was analyzed by considering structural, transportation, and neighborhood attributes in two types of residential property. It was applied to gain better understanding of property values in Jakarta.

This study explored global and local relationship using OLS and GWR tools in ArcGIS software for spatial descriptions and explanations. The following results were obtained:

a. Stations (either bus or train) do not affect the increase in property prices in the surrounding area. Property price is not affected by non-transportation factors such as geographical area, public facility and economic activity.
b. It should be collaboration between government and private sector (either transit point and public transport developer and property developer) to create surrounding area near transit more attractive to be stayed by people. Therefore,- it can uplift property value and increase public transportation dependency.
c. High dependence on private vehicles also affects people's behavior in choosing residential area. A short distance to station is considered a priority in terms of location.
d. The negative impact of a station is more dominant than the positive impact. Environmental conditions need to improve to balance the negative impact from a station.
e. TOD variables, either TOD in a commuter line or BRT stations are not significant regarding an increase in property value, which may be because TOD is still in the planning or designing process. Commuter line stations and BRT stations are still not integrated with each other or with other transportation modes and activities.
f. Generally, the result of GWR is appropriate for the case of Jakarta because it can capture heterogeneous and local variation in Jakarta. Unfortunately, R-squared in GWR is slightly different from OLS because there is the possibility of local collinearity and limitation to analyze binary variables in small data samples.

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