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Land Value Modeling Using Log-Linear Multiple Regression

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Abstract: Land value is an assessment of land based on its economic potential. It is influenced by various factors, including public facilities, road networks, and proximity to supporting infrastructure. Land value information plays a crucial role in infrastructure development, budget planning, and site selection for new infrastructure projects. According to the Surabaya City Regional Spatial Plan (*Rencana Tata Ruang Wilayah* – RTRW) 2014–2034, the development of Teluk Lamong Port, located in the Tambak Osowilangun Subdistrict, aims to enhance national logistics efficiency by alleviating traffic congestion at Tanjung Perak Port, which has exceeded its maximum capacity. This development is expected to affect land values in the subdistrict. Therefore, an objective land valuation is necessary, which can be achieved through modeling. This study employs a Multiple Linear Regression (MLR) approach with a log-lin model to determine land values. The modeling was conducted using 87 land sale and purchase transaction records, which were adjusted based on Circular Letter of the Directorate General of Taxes No. SE-55/PJ.6/1999. The independent variables used in the model include Land Area (LT), Land Use (PL), Distance to Road (JJ), Distance to Port (JPTL), Distance to the Central Business District (JCOP), and Distance to the Terminal (JTTO). The model was evaluated using statistical tests, including the coefficient of determination, partial test, simultaneous test, multicollinearity test, and Coefficient of Variation (CoV) for model evaluation. The resulting land value model is expressed as: Ln NTE = 9.305184 + (1.053730 × PL) + (-0.000450 × JCOP) + (0.000823 × JPTL). The CoV value obtained remains acceptable as it is below 20%, indicating the model's reliability.

Keywords: Infrastructure, Land value, Statistical test, Tambak Osowilangun, Teluk Lamong Port

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Introduction

Land administration plays a crucial role in a country's development, serving as a key instrument for regional planning and sustainable growth (Williamson et al., 2010). The core components of land administration include land tenure, land value, land use, and land development (Dale & McLaughlin, 1999). Land value is defined as the worth of land based on its utilization, representing an assessment of its economic potential (UN-Habitat, 2020). In contrast, land price refers to the nominal monetary value per unit area of land, which is influenced by market conditions and regulatory policies (Munshif et al., 2017). These two concepts share a functional relationship, where a higher land value generally corresponds to a higher land price (Bourassa et al., 2003). Land value is shaped by various factors, including the availability of public facilities, road networks, and proximity to supporting infrastructure (Colwell & Munneke, 1997). As land demand continues to rise, accurate land value information becomes increasingly essential for guiding infrastructure development, budget planning, and the selection of suitable locations for infrastructure projects (Rynjani, 2015; Zhang et al., 2019).

The Ministry of Transportation initiated the development of transportation infrastructure in East Java in 2012, with a budget allocation of IDR 1.709 trillion, an increase from the previous year's allocation of IDR 1.225 trillion. The infrastructure projects included the construction of a 280 km double-track railway from Semarang to Bojonegoro to Surabaya, the development of the Surabaya urban railway (connecting Sidotopo to Juanda International Airport), the second phase of Probolinggo Port development, and the construction of Teluk Lamong Port in Surabaya (Ministry of Transportation, 2012). The development of Teluk Lamong Port aims to enhance national logistics efficiency by alleviating congestion at Tanjung Perak Port, which has exceeded its maximum capacity (Indonesia National Port Master Plan, 2013). This development aligns with the Surabaya City Spatial Plan, as stipulated in Regional Regulation No. 12 of 2014, Article 11, concerning the 2014–2034 Spatial Plan of Surabaya City. The regulation mandates the optimization of the function and role of ports in the Teluk Lamong area and its surroundings as part of the maritime transportation network system development (Ministry of Transportation, 2012).

Teluk Lamong Port, as a key transportation infrastructure in Surabaya, has positively impacted the regional economy by boosting both international and domestic trade. Since its operational launch, the port has contributed to a 15% increase in regional trade volume and a 20% rise in cargo throughput (Pelindo III, 2018). This growth has also led to a 12% increase in land values in the surrounding areas due to improved accessibility and rising investment potential (Surabaya Regional Development Report, 2019). Tambak Osowilangun Subdistrict, covering an area of 90 hectares, is significantly affected as it directly borders Teluk Lamong Port. The continuous development in Tambak Osowilangun has influenced land value information in the region. An objective land valuation can be achieved through modeling, with MLR being a suitable method for land value analysis.

Land valuation models are essential for objectively assessing these changes, with MLR being a widely used method for land value analysis (Akbar, 2020). MLR allows for the examination of various factors influencing land prices, such as infrastructure, accessibility, and economic activity. Several studies worldwide have applied this approach to understand the impact of infrastructure on land values. For example, Debrezion, Pels, & Rietveld (2007) examined the influence of railway accessibility on property values in European cities. Similarly, Zhang et al. (2019) studied infrastructure investment and land value changes in China's metropolitan areas. Despite these global insights, limited research has specifically focused on port infrastructure's direct impact on urban land values, particularly in Indonesia. This study aims to bridge that gap by applying an MLR-based approach to analyze the effects of Teluk Lamong Port on land values in its surrounding areas.

This study models land values in Tambak Osowilangun Subdistrict using several independent variables that have been identified as influential in previous research. The planned dependent variable in this study is land value, while the independent variables include Land Area, Land Use, Distance to Roads, Distance to Ports, Distance to the Central Business District (CBD), and Distance to Terminals. By integrating these variables into a MLR model, this research aims to provide a quantitative framework for understanding the impact of infrastructure, particularly port development, on land value dynamics in Tambak Osowilangun Subdistrict for the period 2017–2022. Unlike previous studies, which primarily focus on urban centers or tourism areas, this research contributes to bridging the gap in understanding how port infrastructure influences land values in peri-urban areas. The findings are expected to serve as a reference for policymakers, urban planners, and investors in making data-driven decisions regarding land use planning and infrastructure investment in port-adjacent regions.

Data and Method

The study area for this research is Tambak Osowilangun Subdistrict, Benowo District, Surabaya City, East Java Province. Geographically, Tambak Osowilangun Subdistrict is located at coordinates 7°11'30" - 7°14'30" S and 112°38'00" - 112°41'00" E, covering an area of 90 hectares. The subdistrict is bordered by the Madura Strait to the north, Tambak Sarioso Subdistrict to the east, Sememi Subdistrict to the south, and Romokalisari Subdistrict to the west.

This study utilizes both spatial and non-spatial data. The spatial data include administrative boundaries of Tambak Osowilangun Subdistrict, obtained from InaGeoportal by Geospatial Information Agency; road network data sourced from OpenStreetMap; a 2022 land-use map acquired from the Regional Development Planning, Research, and Development Agency of Surabaya City; and coordinate data for terminals, ports, and the Central Business District (CBD), extracted from Google Earth Pro due to its high spatial accuracy, ease of access, and up-to-date satellite imagery. Google Earth Pro was selected as a practical alternative to field surveys, which can be time-consuming and resource-intensive, and to supplement official datasets where direct access to institutional records may be limited. Meanwhile, the non-spatial data consist of land sale and purchase transaction records in Tambak Osowilangun Subdistrict from 2017 to 2022, obtained from the Land Data and Information Center for Spatial Planning and Sustainable Agricultural Land. To process and analyze the data, this study utilizes spatial data processing software, word processor, statistical analysis software, and Google Earth Pro.

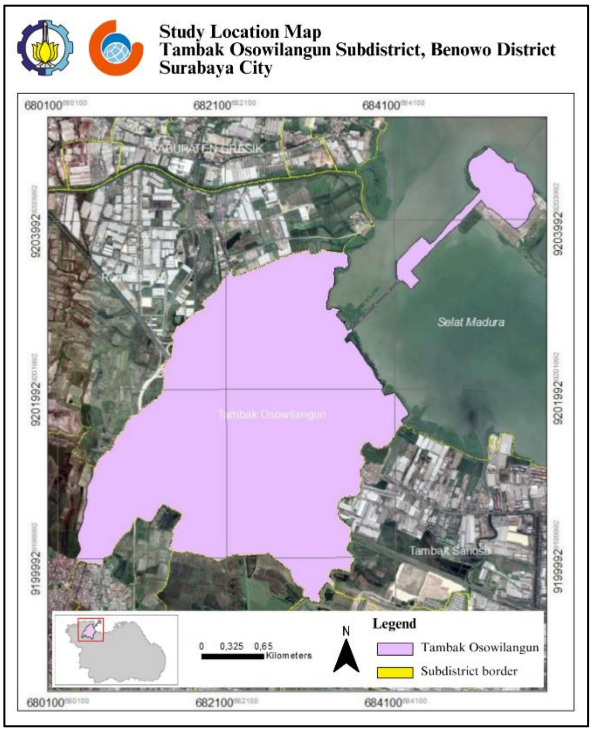

Figure 1. Study Area

The data processing stages in this study begin with the preparation and processing of both spatial and non-spatial data. Coordinate data for terminals, ports, and the Central Business District (CBD) are obtained using Google Earth Pro, which initially uses a geographic coordinate system and must be converted to the UTM coordinate system for consistency with other spatial datasets. These coordinate data, along with road network data, are then processed using spatial data processing software through proximity analysis (Near) to determine the distance from each sample to the land value data.

Since land-use data are qualitative, a weighting process is applied to assign values to different land-use types. The weighting is based on the land-use map obtained from the Regional Public Housing, Settlement Areas, and Land Agency of Surabaya City, where each land-use category is assigned a suitability weight. The weight determination follows the equation proposed by Akbar (2020).

$$r = \frac{\bar{Y}si}{\bar{Y}} \quad (1)$$

$$Nsi = \frac{r}{b} \quad (2)$$

The variables in this study are defined as follows: r represents the ratio of the average land value in each class to the overall average land value. $\bar{Y}si$ refers to the average land value within a specific class, while $\bar{Y}$denotes the overall average land value. Lastly, Nsi represents the variable value (weight) assigned to each class (Table 2). Additionally, land sale and purchase transaction data are corrected for land rights status and transaction time, referencing Circular Letter of the Directorate General of Taxes No. SE-55/PJ.6/1999, with January 1, 2023, as the reference date. Finally, all spatial and non-spatial data are integrated through overlay analysis, resulting in a land transaction distribution map and a corrected land value map, both of which serve as key inputs for land value modeling.

Figure 2. Flowchart of Data Processing

Land value modeling using MLR begins with the identification of independent variables through the coefficient of determination test (R^2), T-test, and F-test. The coefficient of determination (R^2) measures how well the independent variables explain the variance in the dependent variable, with a threshold of $R^2 > 0.5$ indicating a moderately strong model. The T-test is used to assess the statistical significance of each independent variable, ensuring that the variable has a meaningful impact on land value. The criterion for acceptance is $T_{calculated} > T_{table}$, meaning the variable is statistically significant. Meanwhile, the F-test evaluates the overall significance of the regression model by determining whether at least one independent variable significantly affects the dependent variable. The model is considered valid if $F_{calculated} > F_{table}$.

If a variable fails to meet these criteria, variable elimination is performed. This step is necessary to improve the model's reliability by removing variables that do not significantly contribute to the prediction of land values. While eliminating variables might seem like it reduces the model's ability to fully represent reality, keeping irrelevant or weakly correlated variables can introduce noise, reduce accuracy, and lead to overfitting. By excluding such variables, the model becomes more parsimonious, ensuring that only the most influential factors are retained for better generalization and predictive performance.

A multicollinearity test is then conducted to check for high correlations between independent variables using the Variance Inflation Factor (VIF). A VIF < 10 is commonly used as a threshold (Kutner et al., 2005) since values above 10 indicate severe multicollinearity, which can distort coefficient estimates, inflate standard errors, and reduce model reliability. The model is then validated using the Coefficient of Variation (CoV) to measure predictive accuracy. Finally, Inverse Distance Weighting (IDW) interpolation generates the land value estimation map for 2022.

Results and Discussion

Corrected Land Values

From the 87-land sale and purchase transaction records in Tambak Osowilangun Subdistrict between 2017 and 2022, as shown in Table 1, land value correction was carried out using January 1, 2023, as the reference date and freehold title (hak milik) as the reference for land tenure status. Freehold title was chosen as the benchmark because it holds the highest legal status compared to other types of ownership, such as building use rights (*Hak Guna Bangunan – HGB*) and others (Attachment to the Circular Letter of the Directorate General of Taxes, 1999).

Table 1. Land Sale and Purchase Transaction Data

Year	Transaction Data
2017	19
2018	17
2019	12
2020	11
2021	13
2022	15

The results of the land value correction indicate that the lowest land value is IDR 30,250.00/m², associated with land under the right to build status, used for aquaculture, located 123.4 meters from a footpath, 914.0 meters from a terminal, 2,284.34 meters from a port, and 1,066.99 meters from the CBD. Conversely, the highest land value is IDR 22,589,265/m², with freehold status, situated in an industrial area, 45.36 meters from a local road, 664.3 meters from a terminal, 3,590.22 meters from a port, and 619.30 meters from the CBD. The highest land value is located near the Surabaya–Gresik toll road, a major inter-provincial transportation route (Figure 3).

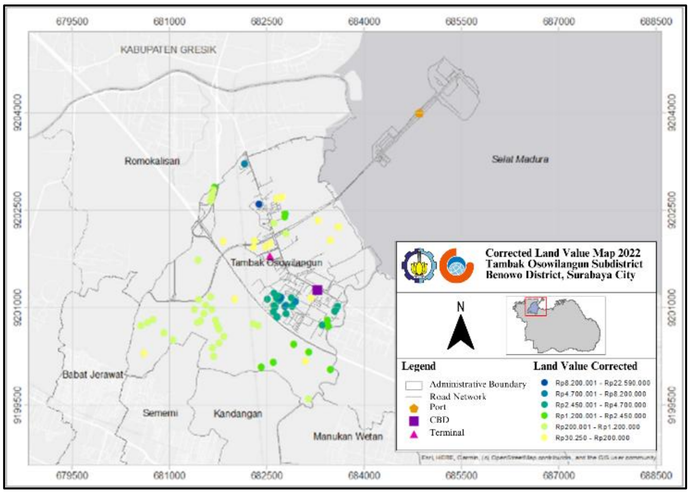

Figure 3. Corrected Land Value Map

Independent Variable

In this study, six independent variables were used to predict land value based on the characteristics of the study area. These variables include Land Area (*Luas Tanah* – LT), Land Use (*Penggunaan Lahan* – PL), Distance to Roads (*Jarak ke Jalan* – JJ) , Distance to Teluk Lamong Ports (*Jarak ke Pelabuhan Telung Lamong* - JPTL), Distance to Tambak Osowilangun Terminal (*Jarak ke Terminal Tambak Osowilangun* – JTTO), and Distance to the Central Osowilangun Parsk as CBD (*Jarak ke Central Osowilangun Park* – JCOP). The land area variable is measured in square meters (m²). The land area data was obtained from land sale transaction records, so no direct measurement was conducted. The largest recorded land area was 60,000 m², while the smallest was 98 m². Meanwhile, the PL variable identifies the type of land utilization. The land use map was created based on the land use zoning map provided by the Surabaya City Office of Housing, Settlements, and Land Affairs. Since land use is qualitative data, a weighting process was applied to each type of land use, as presented in Table 2 and Figure 4.

Table 2. Land Use Weighting

Land Use	Weight
Residential Area	5
Industry	3
Shrubs	2
Aquaculture	1
Mangrove	0
Transportation Area	0

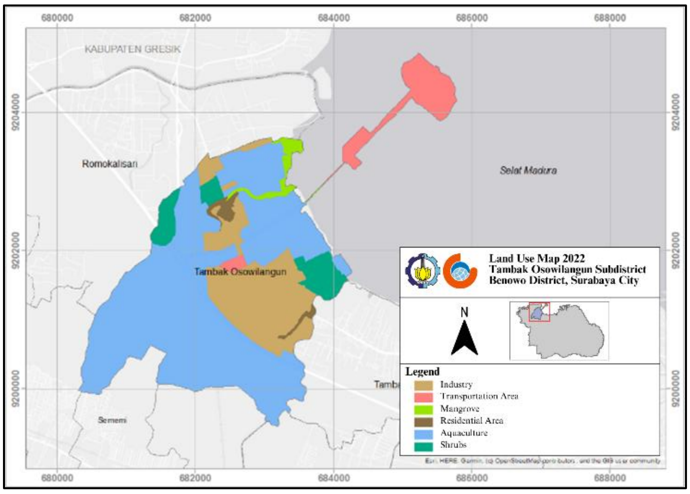

Figure 4. Land Use Map

The JJ represents the distance in meters between a land sample and the nearest road. This variable includes all types of roads, such as toll roads, collector roads, local roads, other roads, and arterial roads. The determination of this variable is conducted using the proximity (near) tool, where the measured distance is the shortest distance from the land sample to the road, without considering the route. The shortest recorded distance to a road from a land sample is 3.221 meters, while the farthest is 888.604 meters. The road network in Tambak Osowilangun Subdistrict is presented in Figure 5.

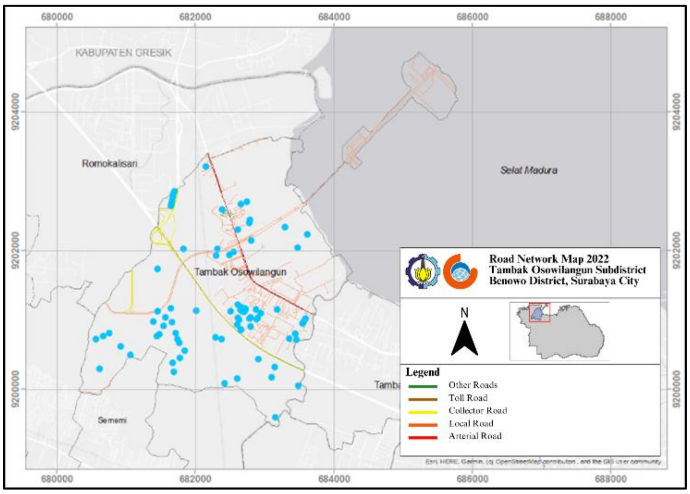

Figure 5. Road Network Map

JPTL is also used as a variable, as it is expected to influence land value in Tambak Osowilangun Subdistrict due to its vital role in trade and transportation. The shortest recorded JPTL is 2,158.477 meters, while the longest is 5,636.522 meters. The fourth variable is the JTTO, which serves as an intercity and interprovincial bus terminal in Surabaya. The JTTO values were obtained using the proximity (near) tool, with the shortest distance recorded at 153.099 meters and the longest at 2,456.311 meters. The last independent variable is JCOP. Central Osowilangun Park is an economic activity zone focused on industrial operations. JCOP was also measured using the proximity (near) tool, with the shortest distance recorded at 162.592 meters and the longest at 2,849.915 meters.

Multiple Linear Regression (MLR)

In MLR modeling for land value, an exploratory analysis of the dependent variable (land value) is crucial to understand its distribution. The histogram results (Figure 6a) indicate a positively skewed distribution, characterized by the absence of a left lobe and a long right tail, which suggests that most land value data are concentrated at lower values, while fewer high-value outliers extend the distribution to the right (Resman, 2019). The corrected land value ranges from IDR 30,250.00/m² to IDR 22,589,265/m², with the peak of the curve around ±IDR 250,000.00/m².

To address this skewness, one effective method is logarithmic transformation. Logarithmic transformation allows a previously nonlinear relationship to be interpreted as a linear model and can adjust data that is not normally distributed to approximate a normal distribution. The logarithmic transformation used in this study follows the log-lin model, where the natural logarithm (Ln) of the dependent variable LT is applied in the MLR model, while independent variables remain in their original form. The histogram results after applying the log-lin transformation indicate a normal distribution, as shown by the symmetric shape of the histogram curve peaking at the center. The corrected land values after logarithmic transformation (Figure 6b) range from 10 to 16, with the distribution peak centered at a value of 13,94.

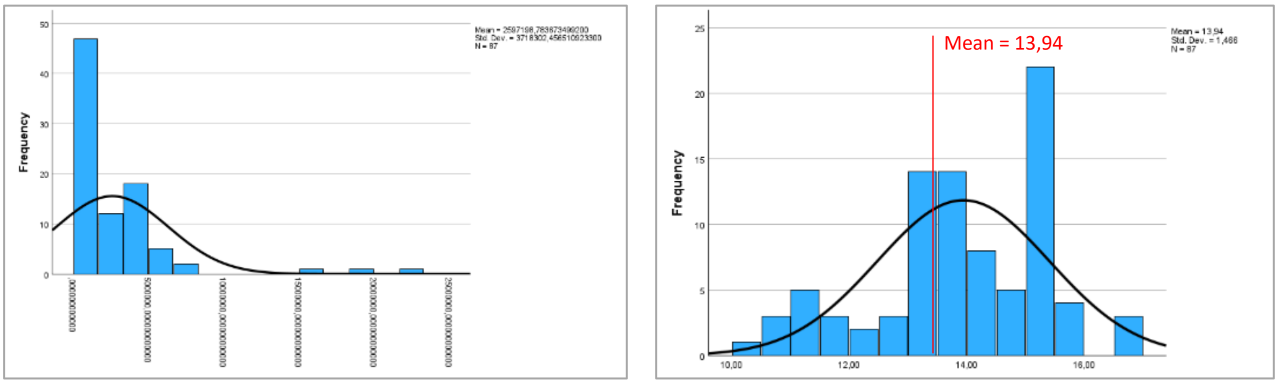

Figure 6. Statistic Histogram : a) Corrected Land Value, b) Corrected Land Value using Log-Lin Model

Statistical Test

Statistical tests are necessary to evaluate the accuracy and reliability of the model in explaining the dependent variable. Several statistical tests were used in this study, including the Coefficient of Determination (R^2) test, which measures how well the independent variables explain the variation in the dependent variable. From the six variables used, the coefficient of determination was found to be 0.6. This value can be categorized as moderately good and acceptable, as the resulting land value model explains 60% of the influence of the independent variables on the dependent variable. However, the remaining 40% of the variation is influenced by other unexamined factors, as suggested in previous research. Studies such as Rahman (2020) and Li et al. (2018) highlight that socioeconomic factors (income levels, purchasing power), environmental conditions (flood risk, pollution levels), land market dynamics (speculation, policy interventions), and spatial factors (topography, accessibility to emerging economic zones) could contribute to the unexplained variation. These factors should be considered in future research to further enhance model accuracy.

The statistical test stage is carried out using the paired sample T-test method, which is a hypothesis testing method with paired data. The purpose of this test is to determine whether the average value of two paired samples is significantly different (Ardiansyah & Irbah, 2024). T-test, is conducted to determine the individual influence of each independent variable on the dependent variable. This Test is performed by comparing the calculated T-value ($T_{calculated}$) with the critical T-value (T_{table}). The $T_{calculated}$ value is obtained through statistical calculations, while T_{table} is derived from the T-distribution table. With a 95% confidence level, the acceptable error tolerance is 0.05. The degree of freedom (df) is determined using the formula df = n-k-1, where n represents the total number of land sale transactions in Tambak Osowilangun from 2017 to 2022, and k is the number of independent variables used. Thus, the degree of freedom is df = 87-6-1 = 80. Based on the T-distribution table, the critical T-value for t (0.025; 80) is 1.990. Farid (2017) explains that if the p-value (significance probability) < 0.05, the independent variable has a significant effect on the dependent variable. The results of the MLR analysis using the log-lin model for the partial T-test of each independent variable on land value are presented in Table 3.

Table 3. T-test Result

Independent Variable	t_{cal}	*Sig.*	Result
LT	-1.996	0.049	Significant
PL	5.291	0.000	Significant
JJ	-0.319	0.750	Not Significant
JCOP	-2.269	0.026	Significant
JPTL	4.044	0.000	Significant
JTTO	0.701	0.485	Not Significant

Based on Table 3, some independent variables did not pass the T-test as they had a T-value lower than 1.990

and a significance value greater than 0.05. These variables are JJ and JTTO, indicating that both variables have minimal impact on land value. Then, the first iteration was performed by removing these two variables, reducing the number of independent variables tested. With degrees of freedom (df) = 87 - 4 - 1 = 82, the T-table value for t (0.025; 82) is 1.989. The first iteration results showed that the LT variable did not pass the T-test. Therefore, a second iteration was conducted with only the remaining three independent variables. In the second iteration, with df = 87 - 3 - 1 = 83, the t-table value for t(0.025;83) was 1.989. The iteration results are presented in Table 4.

Table 4. T-test Iteration

Independent Variable	t_{cal}	Sig.	Result
	First Iteration		
LT	-1.952	0.054	Not Significant
PL	5.971	0.001	Significant
JCOP	-2.011	0.047	Significant
JTTO	5.199	0.001	Significant
	Second Iteration		
PL	8.100	0.000	Significant
JCOP	-2.183	0.032	Significant
JTTO	4.449	0.000	Significant

Additionally, a simultaneous test, or F-test, was conducted to determine whether the independent variables collectively influence the dependent variable. According to Dyah (2012), if the calculated F-value is greater than or equal to the table F-value ($F_{calculated} \geq F_{table}$), it indicates a significant simultaneous effect of the independent variables on the dependent variable. For this F-test, a 95% confidence level was used, with the table F-value obtained from the F-distribution using the following formula:

$$F_{table} = (k; n - k) \quad (3)$$

where k represents the number of independent variables and n represents the total number of transaction data samples. Based on this, the F_{table} for (3.84) is 2.71. From the F-test results, the $F_{calculated}$ was found to be 37.867, with a significance value (Sig.) of 0.001. Since $F_{calculated} \geq F_{table}$ dand Sig. 0.001<0.005, it can be concluded that the independent variables PL, JCOP, and JPTL collectively have a significant effect on land value in Tambak Osowilangun.

The final statistical test conducted was the multicollinearity test, which examines the VIF and Tolerance values in the model. A model is considered free from multicollinearity if the VIF value is less than 10 (VIF<10) or the Tolerance value is greater than 0.01 ($Tolerance > 0{,}01$). The results of the multicollinearity test, as presented in Table 5, indicate that the variables PL, JCOP, and JPTL do not exhibit multicollinearity, as their VIF and Tolerance values fall within the acceptable range. This suggests that these independent variables do not have a strong linear relationship with each other, ensuring the stability and reliability of the regression model (Kutner et al., 2005).

Table 5. Multicollinearity Test

Variable	$Tolerance$	VIF	Result
PL	0.624	1.602	No
JCOP	0.564	1.775	No
JTTO	0.710	1.409	No

Estimated Land Value Model

A land valuation model is a mathematical approach used to determine land value by considering various factors that influence it. Based on the tests conducted, significant influencing variables and the land value model were identified. The land value model equation, derived from MLR coefficients, can be expressed as follows, where NTE represents the Estimated Land Value: $\mathbf{Ln\ NTE = 9,305184 + (1,053730 \times PL) + (-0,000450 \times JCOP) + (0,000823 \times JPTL).}$ Thus, the regression coefficients obtained from the land value model can be interpreted for each independent variable as follows:

a. The regression coefficient for the intercept is +9.305184, meaning that when all independent variables are zero, the estimated land value is 9.305184 on average.
b. The regression coefficient for Land Use (PL) is +1.053730, indicating a positive correlation. This suggests that as the land use score increases, the estimated land value also increases.
c. The regression coefficient for Distance to Central Osowilangun Park (JCOP) is -0.000450, indicating a negative correlation. This means that as the distance to the CBD increases, the estimated land value decreases.
d. The regression coefficient for Distance to Teluk Lamong Port (JPTL) is +0.000823, indicating a positive correlation. This suggests that as the distance to the port increases, the estimated land value also increases.

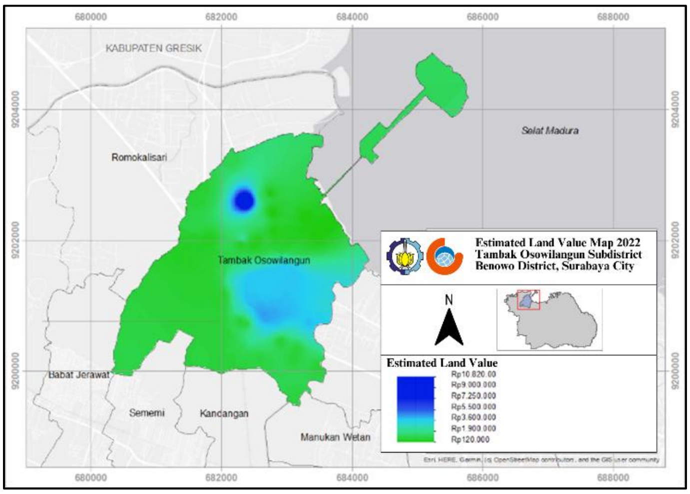

Figure 7. Estimated Land Value Map

A model evaluation was conducted to determine the accuracy of the model in predicting the consistency of the estimated results. The model quality assessment was carried out using the CoV test. The land value model evaluation considered the variables that significantly influenced land value in Kelurahan Tambak Osowilangun, namely PL, JCOP, JPTL. The CoV test results are expressed as the standard deviation in percentage form. The CoV analysis yielded a result of 18.54%. As the CoV value is below 20%, the model remains reliable for land value estimation (Aprianti, 2013).

Inverse Distance Weighting (IDW) interpolation method can be effectively used to create a Land Value Zone (*Zona Nilai Tanah* – ZNT) map, particularly when the selection of land price sample data considers quantity, distribution, and density (Yudanegara, 2021). IDW interpolation was chosen because the number of land value samples used was relatively small, making this interpolation method essential for ensuring a comprehensive representation of land values throughout Kelurahan Tambak Osowilangun. Based on the estimated land value map (Figure 7), the highest recorded land value is IDR 10,820,000/m², while the lowest is IDR 120,000/m². These results align with the statistical modeling conducted, where the lowest land value corresponds to the lowest land use weight (1), classified as aquaculture. Additionally, the location of this land is relatively close to Central Osowilangun Park, at a distance of less than 1 km, and about 2–3 km from the port. Conversely, the highest land value is associated with the highest land use weight (5), classified as residential area, situated approximately 2–3 km from the port and within 1 km of Central Osowilangun Park. The land in Kelurahan Tambak Osowilangun is predominantly used for aquaculture, as indicated by the green color in Figure 7, with an average land value of approximately IDR 1,900,000/m².

Conclusion

Based on the study results, the T-test analysis revealed that among the six independent variables analyzed (LT, PL, JJ, JTTO, JPTL, and JCOP), some variables had a significant influence on land value. In the first iteration, PL, JCOP, and JPTL, were identified as significant variables, while LT was not. The second iteration confirmed these findings, establishing that PL, JCOP, and JPTL significantly influenced land values in Tambak Osowilangun Subdistrict from 2017 to 2022. The land value model for Tambak Osowilangun Subdistrict in 2022 indicates that higher land use weights correlate with increased land values. Additionally, shorter distances to the CBD are associated with higher land values, while greater distances from the port also correspond to higher land values. The derived land value model enabled the estimation of land values, which were visualized using an IDW interpolation-based land value estimation map. The highest estimated land value reached IDR 10,820,000/m², while the lowest was IDR 120,000/m². The highest land values were observed in residential areas near the CBD, whereas the lowest values were found in aquaculture zones near the port. Overall, the dominant land use in Tambak Osowilangun Subdictrict remains aquaculture. For future research, integrating additional variables—such as economic activity intensity, infrastructure development trends, and environmental factors—could improve the land value model's predictive accuracy. Additionally, applying different spatial interpolation techniques or machine learning models may provide more refined land value estimations. Expanding the study area or incorporating temporal analysis across multiple years could also offer deeper insights into long-term land value trends and their driving factors.

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