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Spatial Analysis of Risk Factors for Tuberculosis Incidence in South Jakarta City in 2022

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ABSTRACT

Introduction: South Jakarta City, within DKI Jakarta, bears a substantial burden of TB cases, yet case detection rates and treatment success remain low. Factors such as population density, gender disparity, socio-economic conditions, and healthcare accessibility influence TB transmission. The city's high population density presents challenges in controlling TB spread. Additionally, males and low-income families face higher TB risks.
Objective: This study aims to analyze TB case distribution across 10 districts in South Jakarta, assess TB case clustering, and understand the spatial regression model of TB risk factors.
Method: The methodology of this research utilizes a quantitative approach with an ecological study design and spatial methodology, secondary data from various sources, including the national TB control reporting application. Data processing involves GeoDa v1.22, QGIS v.3.32.3, SPSS v.22, and GWR v4.0 applications for spatial analysis.
Result: Findings reveal that spatial autocorrelation tests using Moran's Index on TB cases in South Jakarta City are not statistically significant, indicating no spatial autocorrelation. The LISA test identifies Mampang Prapatan District as a cold spot in Quadrant III (Low-Low). GWR regression analysis highlights three spatially influential risk factor variables affecting TB cases: gender ratio, number of health centers, and population density. The first two variables affect all districts in South Jakarta City, whereas population density only impacts the Setiabudi District.
Conclusion: In conclusion, Mampang Prapatan district in South Jakarta City exhibits low TB transmission risk, considering population density and other factors. Notably, three spatial risk factors affect TB transmission in South Jakarta City, warranting attention from the health department in TB elimination efforts.

Keywords: Tuberculosis; South Jakarta City; Spatial Autocorrelation; Spatial Regression Model; Districts

INTRODUCTION

Tuberculosis (TB) remains a significant global health challenge, impacting individuals worldwide, including those in Indonesia. In 2021, the World Health Organization (WHO) reported an estimated 10.6 million TB cases globally, resulting in 1.3 million TB-related deaths, including 167,000 deaths among TB-HIV co-infected individuals. Despite global efforts, drug-resistant TB cases persist, with approximately 410,000 cases globally, of which only 175,000 were newly detected. In Indonesia, around 708,000 TB cases were reported out of an estimated 1,060,000 cases in 2022, with a reported mortality rate of 13%. Additionally, approximately 12,000 cases of Drug-Resistant TB (TB-DR) were confirmed out of an estimated 31,000 cases, with only 8,460 cases initiating treatment [4].

South Jakarta City, located in the Special Capital Region of Jakarta, stands out as one of the regions in Indonesia grappling with a high incidence of TB. In this area, TB cases persistently remain high, with detection and cure rates falling below desired targets, especially concerning TB-DR cases. In 2022, TB detection coverage in South Jakarta was a mere 81%, with a Treatment Success Rate of 83%. The burden of TB cases in this region is notably high, exceeding 1000 cases, coupled with treatment rates below 90%. Furthermore, the detection rate for TB-DR cases remains low, with only 152 cases confirmed out of an estimated 292, and a Treatment Success Rate as low as 46% [5]. This high burden of TB cases, coupled with suboptimal treatment success rates, poses a significant risk for future TB transmission [7].

TB spreads through the air when individuals inhale TB-infected droplets, particularly from pulmonary TB patients. It is estimated that a single individual with pulmonary TB can infect 10-15 people in their vicinity, with 5-10% of those individuals developing TB if their immune system is compromised. Therefore, contact with TB patients represents a substantial risk factor for TB transmission. Moreover, high population density in urban areas exacerbates the risk of contact and accelerates TB spread [1]. South Jakarta City, characterized by its high population density, exemplifies this risk, with a population density of 14,475 people per km2. In addition to population density, gender disparity and socio-economic factors significantly influence TB transmission dynamics. In Jakarta, gender distribution in 2021 was relatively balanced, with 49.75% male and 50.25% female, mirroring proportions observed in South Jakarta City. Notably, TB cases detected by health facilities predominantly affect males, with males being 4.9 times more likely to contract TB than females. Additionally, socio-economic status plays a crucial role, as evidenced by studies indicating that families with incomes below the minimum wage are at a higher risk of TB. In Jakarta, poverty is defined by individuals whose average monthly per capita expenditure falls below the Poverty Line, estimated at Rp715,052 as of September 2021. It is estimated that in 2022, Jakarta Province had 502,000 individuals living below the poverty line, with 81,000 residing in South Jakarta City [3].

Moreover, access to healthcare services, including healthcare personnel, is vital for effective TB control. A lack of healthcare personnel can impede access to healthcare services, leading to challenges such as delayed diagnosis, treatment access issues, increased mortality rates, and hindered economic growth. A study conducted across 407 districts/cities in Indonesia in 2020 found that an increase in healthcare personnel negatively impacted the number of individuals living in poverty [14].

Given the multifaceted nature of TB transmission dynamics and associated risk factors, this study aims to elucidate the distribution of TB cases across the 10 districts of South Jakarta City. Additionally, the study seeks to investigate TB case clustering and population density in the area. Furthermore, the researchers aim to develop a spatial model for TB transmission risk factors to identify spatially influential factors affecting TB case numbers in each district of South Jakarta City. The insights garnered from this study are anticipated to inform decision-making processes regarding TB control interventions in South Jakarta City.

METHOD

This study adopts a quantitative approach with an ecological study design, employing a spatial methodology to ascertain the distribution, clustering pattern, and spatial model of risk factors associated with the percentage of TB cases across the 10 districts of South Jakarta City. The study utilizes secondary data in the form of aggregate data derived from the 10 districts within South Jakarta City. Research variables encompass the percentage of TB cases, population density per km2, the number of impoverished individuals, sex ratio, healthcare personnel count (including doctors, nurses, and midwives), and the number of health centers. Data concerning TB cases and health centers were sourced from the national TB control report mobile application, accessible to the public. TB case data for 2022 were obtained from reported cases documented by healthcare facilities. Data relating to other variables were collected from the Jakarta Central Bureau of Statistics and the South Jakarta Central Bureau of Statistics in 2023, pertaining to the year 2022. Data processing and analysis entail visualization of areas based on TB case numbers, identification of TB case distribution or clustering areas via exploratory methods, and comprehension of the spatial model of TB risk factors within the DKI Jakarta Province. Spatial data processing, analysis, and result interpretation are conducted using GeoDa v1.22, QGIS v.3.32.3, SPSS v.22, and GWR v4.0 applications.

The initial analysis consists of descriptive analysis to characterize each researched variable using the SPSS application. Subsequently, mapping is employed to depict the distribution of variable values across the 10 districts in South Jakarta City. The subsequent analysis involves spatial autocorrelation analysis using the GeoDa application. Tests include the Global Moran's Index and LISA (Local Indicators of Spatial Association) tests. Prior to these tests, spatial weighting or neighbor definition is executed. In this study encompassing the 10 districts of South Jakarta City, the rook type of adjacency is utilized, wherein adjacency is determined based on locations above, below, left, and right on the map. In the autocorrelation test, the Moran's Index (I) value is scrutinized. The null hypothesis posits no correlation between region values if I = 0 (H0), while spatial autocorrelation between regions is indicated if $I \neq 0$ (H1). Additionally, the p-value and I to E(I) ratio are evaluated. A p-value ≤ 0.05 indicates statistically significant spatial autocorrelation. Furthermore, the I to E(I) ratio is assessed to observe distribution patterns. A value of $I > E(I)$ signifies a positive or clustered distribution pattern, while $I < E(I)$ indicates a negative or dispersed pattern. The Moran's Index test can also generate a cluster map, delineating hotspot areas (in Quadrant I or High-High) and cold spot areas (in Quadrant III or Low-Low).

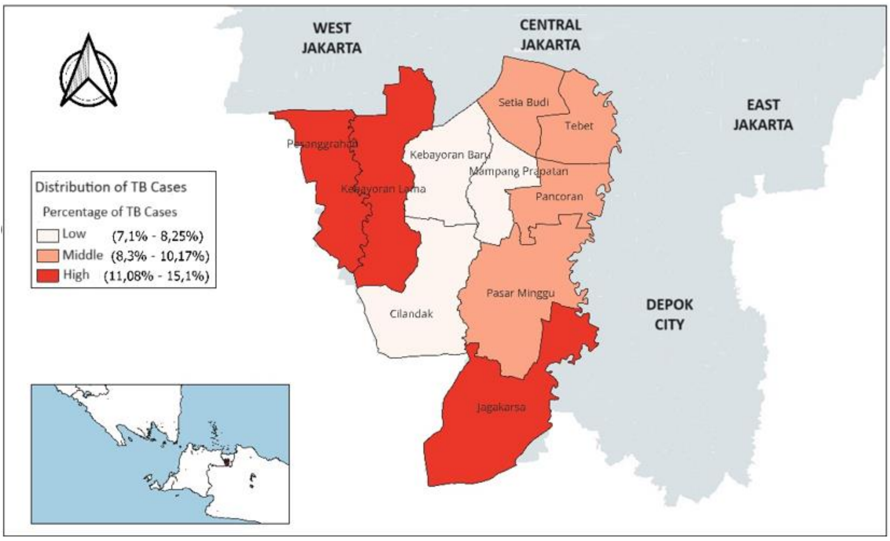
Subsequently, to construct a spatial regression model, statistical modeling analysis is imperative. Geographically Weighted Regression (GWR) analysis is utilized in this study to comprehend the spatial model of factors influencing the number of TB cases across the 10 districts of South Jakarta City. However, prior to conducting GWR analysis, classical assumption tests or Ordinary Least Square (OLS) tests are essential, encompassing normality, variance, and multicollinearity tests, ensuring that the test result estimates yield residuals that are normally distributed, homogenous, and independent [16]. Additionally, tests for residual normality assumption, independence via the Durbin-Watson (DW) test, multicollinearity, and homoscedasticity or variance through the Breusch-Pagan Test should be executed [13].

RESULTS

The descriptive statistics test results presented in Table 1 illustrate the distribution of research variables based on statistical analysis and in Picture 1 show the distribution of TB cases in 10 districts. The table reveals that the percentage of TB cases across 10 districts in South Jakarta City in 2022 ranged from 7.1% in Cilandak to 15.1% in Jagakarsa [5]. Regarding population density, the average density was 31,986 individuals per square kilometer, with the highest density observed in Pasar Minggu district (114,987 individuals per square kilometer) and the lowest in Setia Budi district (4,832 individuals per square kilometer). The average gender ratio was 0.98, with the lowest ratio found in Kebayoran Lama district (0.94) and the highest in Mampang Prapatan district (1.02). Additionally, the average area size was 14.13 square kilometers, with the smallest area in Mampang Prapatan district (7.73 square kilometers) and the largest in Jagakarsa district (24.87 square kilometers). Concerning the number of impoverished residents, the average count was 8,471 individuals, with the lowest in Setia Budi district (4,167 individuals) and the highest in Jagakarsa district (13,144 individuals). The average count of healthcare workers was 1,080 individuals, with the lowest in Mampang Prapatan district (183 individuals) and the highest in Cilandak district (2,452 individuals). Lastly, the average number of health centers was 7.5, with the lowest count in Cilandak, Mampang Prapatan, Pesanggrahan, and Tebet districts (6 health centers each) and the highest in Pasar Minggu district (10 health centers).

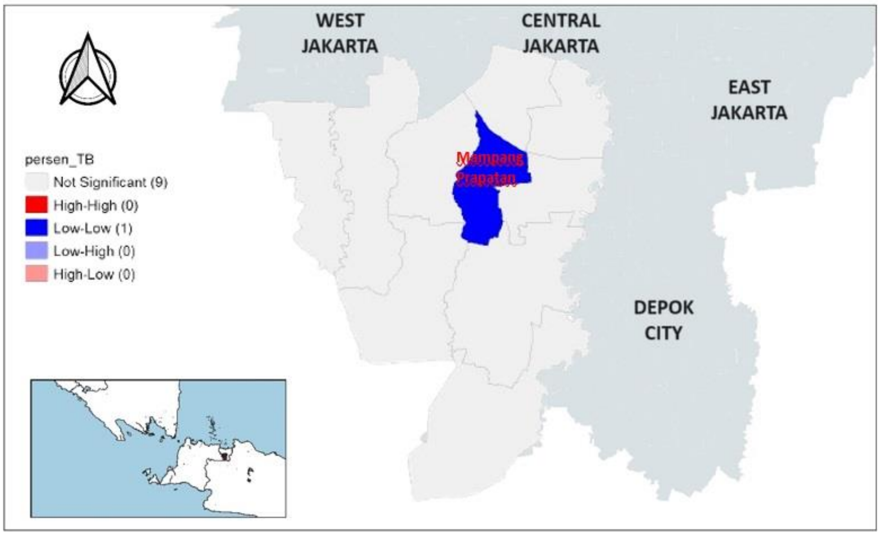
Table 1. The Distribution of Variables Based on Descriptive Statistical Test Results

Variable	N	Minimum	Maximum	Mean	Standard Deviation
Percentage of TB cases	10	7.1	15.1	10	2.34
Population density	10	4,832	114,987	31,986	3,3571
Gender ratio	10	0.94	1.02	0.98	0.02
Area size	10	7.73	24.87	14.127	6.01
Impoverished residents	10	4,167	13,144	8,471	3,078.1
Number of healthcare workers	10	183	2,452	1,080	651.52
Number of health centers	10	6	10	7.5	1.5



Picture 1. Map of TB Case Distribution in 10 Districts in South Jakarta City, 2022

The spatial autocorrelation test results indicated positive spatial autocorrelation in TB case distribution among the 10 districts in South Jakarta City, suggesting a clustered pattern where neighboring areas tend to exhibit similar TB case percentages. However, the non-significant p-value (0.259 > 0.05) indicates that the observed autocorrelation is not statistically significant. Furthermore, the LISA analysis identified Mampang Prapatan district as a statistically significant cold spot (Low-Low), indicating a low prevalence of TB cases surrounded by neighboring districts with similarly low TB case percentages. (Picture 2)



Picture 2. Map Cluster of TB Case Distribution in 10 Districts in South Jakarta City, 2022

Prior to spatial regression analysis, normality assumption testing using the Kolmogorov-Smirnov test yielded a p-value of 0.200, indicating normal distribution of the data. Multicollinearity assumption testing based on Variance Inflation Factor (VIF) values showed no multicollinearity issues, with all independent variables having VIF values < 10 and tolerance values > 0.1. The scatter plot results also indicate the absence of a clear distribution or pattern, with points scattered above and below the 0 mark on the Y-axis, suggesting no heteroscedasticity. Additionally, the Breusch-Pagan test yields a p-value > 0.05, indicating homogeneity of residual variance. Moreover, the goodness-of-fit test for multiple linear regression shows an AIC value of 45.783 and an R-squared value of 76.6%, suggesting that the TB risk factor model being investigated can account for 76.6% of the TB case variation in South Jakarta City, with the remaining explained by other factors beyond the variables studied.

The analysis using GWR reveals that the global regression model yielded an AIC value of 36.386 with an R-squared value of 90.65%. Meanwhile, the suitability test of the GWR model with fixed Gaussian weighting produces a minimum CV value of 4495.251 and an optimum Bandwidth of 1712.082. The AIC value for the GWR model is -280.43 with an R-squared value of 100%. Both values indicate that the GWR model outperforms the global regression model, as the AIC value is smaller, and the R-squared value is larger.

Furthermore, the GWR ANOVA analysis results in an F value of 10.16 with df 1 of 3 and df 2 of 3 at α=0.05. The critical F value with a significance level of 0.05 is 9.28. Therefore, the calculated F value > the critical F value, indicating that the null hypothesis is rejected, suggesting that the model is appropriate. To examine the spatial relationship of independent variables with the percentage of TB cases in South Jakarta City, the Diff of criterion values are considered, where negative values suggest a spatial relationship. In this study, variables such as gender ratio, area size, population density, number of healthcare workers, and number of impoverished residents have negative values, implying spatial relationships. However, the number of health centers variable does not have a negative value, indicating no spatial relationship with the percentage of TB cases in South Jakarta City. Overall, the GWR model provided a better fit than the global regression model, as indicated by lower AIC values and higher R-squared values. Additionally, the ANOVA test confirmed the suitability of the GWR model for the data.

The spatial model of TB risk factors per sub-district in South Jakarta City using GWR analysis that compares the t-value for each parameter with the critical t-value. A positive and greater calculated t-value than the critical t-value implies the variable's impact on the observation location. Conversely, negative t-values indicate an effect if smaller than the negative critical t-value. Employing a significance level of 0.05, the critical t-value utilized is 2.776 (with α = 0.05 and degrees of freedom df = n-k (10-6) = 4) [8]. The result of the analysis in each variable are presented in table 2.

Table 2. The Results of GWR Model Analysis of TB Risk Factors in South Jakarta

Variable	β (ui, vi)			
	Minimum	**Maximum**	**Mean**	**Range**
Intercept	-2,69225	70,32752	12,46218	73,01977
Population density	-0,000057	0,000272	0,000032	0,000329
Gender ratio	-0,610284	0,009552	-0,05723	0,619836
Area size	0,001558	0,00999	0,004741	0,008432
Impoverished residents	-0,000532	0,000957	0,000057	0,001489
Number of healthcare workers	-0,004851	0,000868	-0,00188	0,005719
Number of health centers	-1,512125	0,738483	-0,3186	2,250608

DISCUSSION

The analysis of the GWR model suggests that each sub-district in South Jakarta City possesses coordinates yielding distinct coefficient estimates for specific parameters or variables, along with observation locations impacting TB case occurrences. Consequently, each area manifests a unique model elucidating the TB risk factors. These formulated variables undergo testing to ascertain their significant influence as risk factors in each district. All t-values for the gender ratio variable in the 10 areas exceed the critical t-value, suggesting its influence on TB case percentages in all 10 districts. Prior studies have similarly shown gender's impact on TB cases regionally. For instance, a study on the spatial epidemiology of pediatric pulmonary TB cases in Medan City from 2016 to 2020 indicated a higher prevalence among males compared to females [9].

In contrast, the calculated t-values for the area size variable are smaller than the critical t-value in all 10 areas, concluding that it does not affect TB case percentages. However, concerning population density, only Setia Budi District exhibits a t-value surpassing the critical value, indicating significant influence solely in this district. A prior study by Srisantyorini et al. in 2022 also unveiled a significant correlation between population density and pulmonary TB case spread (P-value = 0.001 and r = 0.7) [15]. Yet, spatially, population density has been shown not to correlate with TB incidence rates in other studies [2]. The t-values for the healthcare worker variable in all areas are smaller than the critical t-value, suggesting its lack of impact on TB case percentages in the 10 districts. This result is not in line with the research conducted by Nisa et al. in 2016 on modeling the factors influencing the number of tuberculosis cases in East Java using non-parametric spline regression. The number of trained healthcare workers for TB is one of the variables that significantly influences the number of TB cases in East Java [17]. Furthermore, the t-values for the number of health centers variable in all areas exceed the critical t-value, indicating its effect on TB case percentages in the 10 districts. Lastly, for the impoverished resident's variable, the calculated t-values in all areas are smaller than the critical t-value, implying no influence on TB case percentages. This contradicts previous studies, such as research by Saputra et al. in 2020, which demonstrated that poverty rates spatially influence TB occurrences in Bali Province [11].

CONCLUSION

In summary, the classical assumption tests confirmed that the dependent variable and the 6 independent variables met the required criteria, demonstrating normal distribution, absence of multicollinearity, and homoscedasticity. However, the spatial autocorrelation test using Moran's Index on the dependent variable (percentage of TB cases) across the 10 districts of South Jakarta City did not yield statistically significant results, indicating the absence of spatial autocorrelation. Nonetheless, the LISA test identified one area as a significant cold spot, located in Quadrant III (Low-Low), suggesting that this district has a notably low percentage of TB cases and is surrounded by neighboring districts with similarly low TB case percentages. Furthermore, considering population density and other risk factors such as area size, the prevalence of impoverished population, as well as the availability of health centers and healthcare personnel, this area also demonstrates low-risk indicators.

Regarding the regression model analysis utilizing the GWR model, it was observed that three spatially influential risk factor variables affect the percentage of TB cases. These variables encompass the gender ratio and the number of health centers, impacting all districts within South Jakarta City. Another variable, population density, exerts influence solely on one district in South Jakarta City, specifically Setiabudi District. Hence, it is imperative for the local government of South Jakarta City to give particular attention to addressing these three spatially influential risk factors that contribute to the percentage of TB cases in each district.

SUGGESTION

The findings carry significant implications for crafting policies and intervention strategies aimed at controlling TB in South Jakarta City. For instance, enhancing access to healthcare services through the expansion of health centers could prove to be a viable strategy for diminishing TB incidence across various districts. Nonetheless, this study is subject to certain limitations, specifically, the data utilized is confined to TB patients documented at health centers within South Jakarta City. Suggestions for future research entail utilizing TB data based on patients' residential addresses and incorporating qualitative data on additional factors that could potentially impact TB cases, including environmental and socio-economic factors.

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