Child Marriage and Infant Mortality in Indonesia: A Spatial Analysis Approach

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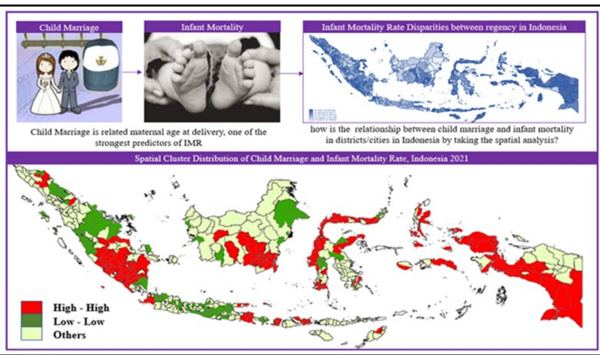
ABSTRACT

Spatial analysis approach is capable of identifying spatial clustering of Infant Mortality Rate (IMR) across districts/cities in Indonesia. This information is essential for policymakers when developing appropriate health interventions at districts/cities level. At delivery, maternal age is one of the strongest predictors of infant mortality, which is closely related to child marriage. Therefore, this study aimed to determine the relationship between child marriage and IMR in Indonesia, which was controlled by the influence of maternal, household, and health factors. The results showed that there were spatial dependency on IMR in Indonesia. Analysis Regression Spatial Durbin Model showed that child marriage had a positive and significant relationship with IMR. Furthermore, it was discovered that IMR was influenced by several explanatory variables in districts and neighboring cities. To reduce mortality rate, there was a need to increase health services by developing neighboring areas and building access to areas with good health facilities. Educational initiatives are also important, emphasizing the importance of delaying the age of marriage and enforcing the minimum age limits. This approach empowered every child to marriage carefully and had good reproductive health knowledge that could decrease IMR in Indonesia.

ABSTRAK

Pendekatan analisis spasial dapat mengidentifikasi pengelompokkan spasial AKB kabupaten/kota di Indonesia yang sangat penting bagi pembuat kebijakan saat menyesuaikan intervensi kesehatan yang tepat pada tingkat kabupaten/kota. Usia ibu saat melahirkan merupakan salah satu prediktor terkuat kematian bayi, yang berkaitan erat dengan perkawinan usia anak. Dengan mempertimbangkan efek spasial antar kabupaten/kota, maka studi ini bertujuan untuk mempelajari hubungan perkawinan usia anak dengan AKB di Indonesia yang dikontrol oleh pengaruh faktor ibu, rumah tangga, dan kesehatan. Hasil analisis menunjukkan adanya dependensi spasial pada AKB di Indonesia. Analisis Regresi Spasial Model Durbin menunjukkan bahwa perkawinan anak mempunyai hubungan yang positif dan signifikan dengan AKB. Selain itu, AKB tidak hanya dipengaruhi oleh variabel penjelas dalam kabupaten/kota tersebut melainkan juga dipengaruhi oleh AKB dan beberapa variabel penjelas di kabupaten tetangga. Oleh karena itu, untuk menurunkan AKB perlu dilakukan pengembangan wilayah sekitar, membangun akses wilayah dengan fasilitas kesehatan yang baik sehingga pemanfaatan pelayanan kesehatan meningkat dan menurunkan AKB. Edukasi mengenai pentingnya pendewasaan usia pernikahan dan menegakkan aturan batas usia minimal perkawinan sangat diperlukan agar remaja dapat merencanakan pernikahannya dengan matang dan memiliki pengetahuan kesehatan reproduksi yang baik sehingga dapat menurunkan AKB Indonesia.

GRAPHICAL ABSTRACT



Keyword
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INTRODUCTION

Infant mortality is a crucial factor in public health, acting as an indicator of health development and quality of life (Santiago & Tubayan, 2016; Santy, 2018). A high Infant Mortality Rate (IMR) reflects unfavorable social, economic, and environmental conditions during the first year of life (Weldearegawi et al., 2015). Despite the decrease in IMR from 65 in 1990 to 27 deaths per 1000 live births in 2020, it still accounts for 73% of all under-five deaths worldwide (WHO, 2023). This high proportion has made reducing infant mortality a top priority on the policy agenda in several countries (Garcia-Hombrados, 2021). In the 2019-2024 National Medium Term Development Plan (RPJMN), Indonesia has set a target to decrease IMR to 16 per 1000 live births by 2024. According to Unicef (2023), IMR in Indonesia was 20 deaths per 1000 live births, surpassing neighboring countries such as Singapore, Malaysia, and Brunei Darussalam. This discrepancy impacts life expectancy, showing that health development in Indonesia is still lacking compared to neighboring countries.

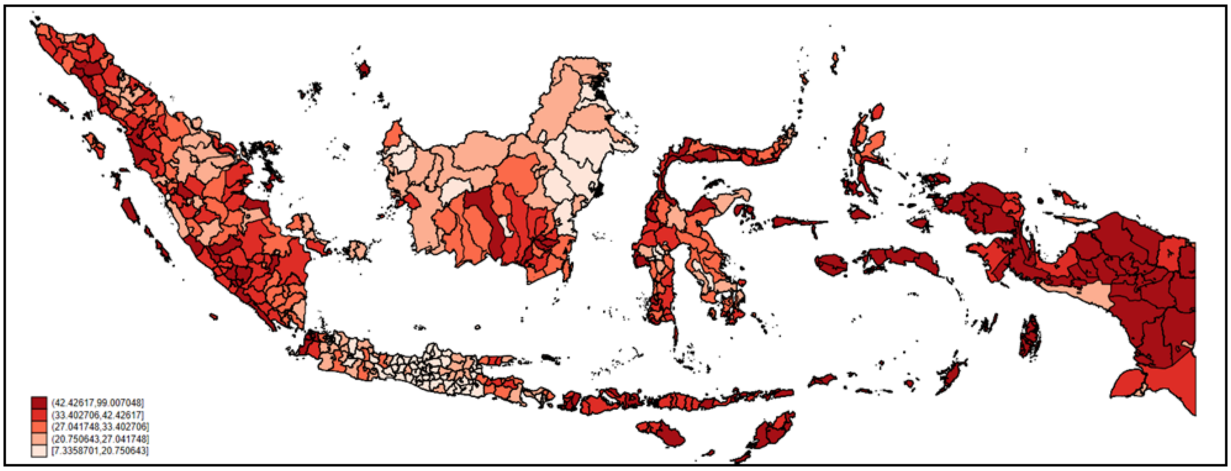
The degree of population health, reflected in high IMR, is one of the development problems in Indonesia (Santy, 2018). Meanwhile, the slow reduction in IMR is due to regional inequalities (Gupta et al., 2016) and geographical factors, as shown in Figure 1. These phenomena lead to high IMR disparities, as most cities have higher rates than the Indonesian national average. In 2021, the ratio of the highest and lowest IMR was projected to reach 14 times, which are majorly concentrated in eastern and western areas, respectively.

Previous studies showed the existence of a geographical influence on IMR, indicating the importance of spatial risk factors in explaining the differences (Gupta et al., 2016; Rashid & Chand, 2016; Singh et al., 2011). Gupta et al. (2016) stated that adjacent areas had spatial dependency resulting in regional grouping of IMR. This geographical disaggregation persisted after accounting for all household, maternal and child, health care, and health facility variables. Santy (2018) showed that IMR in Indonesia was spatially influenced by socioeconomic, health, and environmental factors. However, studies using spatial analysis did not consider the influence of maternal age, a strong predictor and significant covariate influencing differences in IMR between countries (Ram et al., 2021; Gouda et al., 2015). Becoming a mother at a very young age is often related to child marriage which has negative impacts, including infant mortality (Jensen & Thornton, 2003; Solanke, 2015; Neal et al., 2018).

Child marriage is an important cause of infant mortality due to early exposure to the risk of pregnancy (Solanke, 2015; Ertem et al., 2008). Girls who are married at a young age are prone to give birth prematurely, increasing the risk of maternal and child morbidity such as complications of childbirth, fistulas, low birth weight, and malnutrition. High rates of child marriage in certain areas correlate with greater IMR (Raj & Boehmer, 2013), significantly increasing global concern (Hossain et al., 2022). Indonesia is a country with a high number of child marriages, accounting for 1,220,900 women aged 20-24 years, who were married before reaching 18 years. This prevalence makes Indonesia among the 10 highest child marriage rates globally, ranking second in Southeast Asia (BPS et al., 2020). In 2021, there were approximately 9.23% child marriage, showing that 1 among 11 women aged 20-24 were married before the age of 18.

Previous studies on child marriage and infant mortality have predominantly focused on individual, household-level, socioeconomic, and community-environmental risk factors ignoring the crucial effects of geographic factors. Garcia-Hombrados (2021) showed the causal influence

Figure 1
IMR by Districts/Cities in Indonesia, 2021



Note : Geoda 1.20 processing results

of child marriage on infant mortality. Another study in Bangladesh showed that children born to mothers who engaged in child marriage experienced a higher mortality rate in the first year of life compared to other siblings (Trommlerová, 2020). This is because child marriage leads to early, frequent, and unplanned pregnancies that are consistently associated with a high increase in infant mortality (Raj et al., 2010). The analysis suggests that the relationship between child marriage and infant mortality is homogeneous across areas, potentially introducing bias into the model (Singh et al., 2011). A research gap exists in the analysis of child marriage on infant mortality by considering geographical factors. Each aggregation of socioeconomic, demographic, and health variables in geographic space tends to show spatial patterns describing geographic distribution (Singh et al., 2011). Consequently, this research aimed to determine the relationship between child marriage and infant mortality using spatial approach to reduce estimation bias due to the interrelationships of areas that are not independent of each other.

The research hypothesis stated that districts/cities with high child marriage had elevated IMR and there were spatial effects affecting infant mortality in Indonesia after accounting for the influence of maternal, household, and health factors. Therefore, this research aimed to analyze the relationship between child marriage and infant mortality by considering spatial effects between districts/cities.

METHODS

This research used data derived from the 2021 National Socioeconomic Survey, National Labor Force Survey, and Village Potential, BPS-Statistics Indonesia. The unit of analysis used is 514 districts/cities in Indonesia, with IMR sourced from BPS at the provincial level serving as the dependent variable. To obtain the districts/cities IMR, a conversion from Life Expectancy at Birth (e^o) was used for estimation (Santy, 2018). The conversion steps were as follows: (1) Break down e^o the total for each district/city into e^o male (e^o_m) and e^o female (e^o_f) using proxies from the life table of the World Population Prospect for the country of Indonesia for the 2015-2020 period. (2) Determine the appropriate level based on e^o_m and e^o_f using the Coale-Demeny model west life table. (3) Do the interpolation to obtain male and female IMR in each district/city according to predeter-

Table 1
Variables Used in Research

Variable Name	Code	Criteria
Dependent variable		
Infant Mortality Rate	IMR	Convert from life expectancy at birth.
Main Independent Variables		
Child Marriage	CM	The proportion of women aged 20-24 who were first married before the age of 18.
Control Variable (X)		
Women's Education	Educ	Mean Years School of women ≥ 15 years.
Women's Labor Force Participation Rate	WLFP	The proportion of the female population in the labor force to the working-age population.
Poverty	poor	Percentage of population below the Poverty Line.
Household Size	HHsize	The average number of household members living in one household.
Clean Water Access	water	Percentage of households that have access to clean water (bottled water, refills, piped water, drilled wells, protected wells, and protected springs) with a minimum distance of ten meters to disposal and have a toilet and septic tank final disposal site.
Cooking Fuel	cook	Percentage of households using solid fuels including coal, straw, charcoal, firewood.
Immunization	DPT	Percentage of children under five who have received DPT immunization in each district/city.
Safe Delivery	delivery	Percentage of deliveries performed in health facilities and handled by competent health personnel.
Number of Health Facilities	health	Number of Hospital facilities, Maternity Hospitals, Inpatient Health Centers, Health Centers, Maternity Clinics, and Maternity Midwives in Districts/Cities per 1000 inhabitants.

mined levels. (4) Calculate the total IMR for each district/city using the formula 1.

$$(105 \times IMR_{male} + 100 \times IMR_{female})/205 \quad (1)$$

In the analysis, 205 represents the total number of infants as the sex ratio birth is 1.05. The variables and explanations used in this research are summarized in Table 1.

This research used a descriptive-analytical method, providing univariate and bivariate analyses, while spatial clusters of IMR using Explanatory Spatial Data Analysis (ESDA) were identified. Analysis of ESDA was carried out using the value of inter-regional linkages based on spatial autocorrelation (Anselin, 1988). ESDA analysis used the Moran Scatterplot, describing the relationship between the observed (z) and neighboring areas' observation value (spatial lag Wz), categorizing the observation area into quadrant I (high-high), quadrant II (low-high), quadrant III (low-low), and quadrant IV (high-low).

Inferential statistics is carried out using spatial regression analysis to evaluate the impact of child marriage and control variables on IMR, along with spatial effect between one district/city and neighboring districts/cities. Spatial analysis method is more appropriate for data with regional linkages compared to the Ordinary Least Square (OLS) method, which assumes each observation is independent, resulting in biased estimates. Spatial weight matrix (W) is the contiguity matrix from the intersection of districts/cities borders (Anselin & Rey, 2014).

In this research, the selection of an appropriate spatial regression model was carried out using the Lagrange Multiplier test, comprising LM-lag, LM-error, Robust LM (lagged), and Robust LM (error), to determine a better Spatial Autoregressive Model (SAR) or Spatial Error Model (SEM) (LeSage, 1999). The results

Table 2
Output of Econometric Spatial Model Identification on IMR

test	*Value*	*P-values*
LM (lag)	109.422	0.0000***
Robust LM (lagged)	19.755	0.1599
LM (error)	1094.532	0.0000***
Robust LM (error)	858.751	0.0000***
LR (SAR-SDM)	1179.500	0.0000***
LR (SEM-SDM)	245.400	0.0063*

Note: The estimated coefficient is significant at *p≤ 0.1; ** p≤ 0.05; ***p≤ 0.

of LM-lag and Robust LM (lagged) test show the presence of spatial dependency on the dependent variable, suggesting the use of SAR. Meanwhile, when LM (error) and robust LM (error) test results are significant, it shows spatial dependency for errors, indicating the suitability of SEM model. A particular case of SAR model is Spatial Durbin Model (SDM), characterized by the addition of spatial lag in the dependent variable and spatial cross in the independent variable (LeSage & Pace, 2009). The selection of SDM model with SAR and SEM was carried out through LR test, where SDM was more appropriate. Moreover, ethical permission was not required in this research due to the use of secondary data.

RESULTS

Based on the results of Moran's I test, a value of 0.615 was produced with a p-value of less than 1%, showing spatial dependency on IMR variable by districts/cities in Indonesia. Similarly, Santy (2018) and Pramono et. al (2012) observed spatial dependency on infant mortality, showing the presence of similarities or groupings of IMR in adjacent districts/cities. The results of Moran's I test show that spatial modeling is feasible to use. The selection of the optimal model for spatial analysis was based on LM, Robust LM, and LR tests. Based on the analysis, LM and robust LM tests were used to examine the optimal model between SAR and SEM, while LR test was used to determine the optimal model between SDM with SAR and SEM. As shown in Table 2, LM lag and error tests showed significance in both SAR and SEM models. The analysis proceeded with robust LM, indicating SEM as the best model with a lower p-value < 0.001, while SAR is not significant on robust LM. The results of LR test showed that SDM was more suitable than SAR and SEM, as indicated by a p-value <0.001 for SAR and 0.01 for SEM. Therefore, the model used in this research was SDM, accommodating cross-spatial dependency on IMR and spatial independence on explanatory variables.

According to Table 3, OLS results show a higher beta coefficient value compared to SDM, which is corrected with the bias of the over-estimated beta coefficient of 10.9%. Additionally, HR results produce an estimate of beta in child marriage with a lower standard of error than OLS. Based on Akaike's Information Criterion (AIC) value, HR spatial regression model has a lower value than OLS, specifically 3680.571 compared to 3784379. The model with the minimum AIC is considered the best, capable of explaining the suitability with the existing data (Akaike, 1974). Based on the maximum probability value, OLS also has a lower value of -1881.190 compared to SDM at -1817.285. The results show that HR spatial regression model is more appropriate to use in this study than OLS.

Regarding the significance level in

Table 3
Estimation of Spatial Regression Coefficient Durbin Model and OLS

Variable	*Spatial Durbin Model*	OLS
CM	0.191*** (0.071)	0.214*** (0.076)
educ	-0.881* (0.482)	0.150 (0.469)
WLFP	-0.125*** (0.049)	-0.140*** (0.051)
poor	0.380*** (0.094)	0.441*** (0.085)
HHsize	5.980*** (1.198)	4.438*** (1.174)
water	-0.048 (0.034)	-0.108*** (0.032)
cook	0.069** (0.034)	0.070** (0.031)
DPT	-0.107 (0.101)	-0.537*** (0.099)
delivery	-0.062** (0.030)	-0.038 (0.032)
health	-22.886** (11.318)	-31.574*** (11.930)
Constant	24.529*** (7.399)	27.778*** (7.733)
Rho	0.583*** (0.065)	
Wc_CM	0.017 (0.146)	
Wc_educ	1.767* (1.092)	
Wc_WLFP	0.109 (0.103)	
Wc_poor	-0.249 (0.182)	
Wc_HHsize	-9.284*** (2.246)	
Wc_water	-0.006 (0.075)	
Wc_cook	-0.019 (0.074)	
Wc_DPT	-0.775*** (0.229)	
Wc_delivery	0.156** (0.072)	
Wc_health	-39.279 (27.439)	
ML	-1,817,285	-1,881,190
AIC	3,680,571	3,784,379

*Note: The estimated coefficient is significant at *p≤ 0.1; ** p≤ 0.05; ***p≤ 0.01*

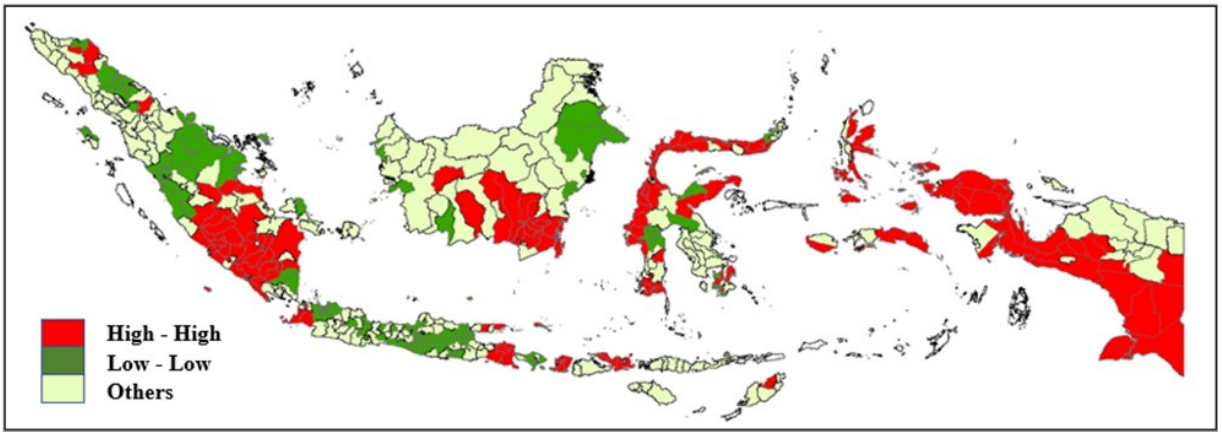
Table 3, districts/cities IMR in Indonesia are statistically significantly influenced by child marriage, women education, female labor force participation rate, poverty, the average number of household members, fuel for cooking, birth assistance, and number of health facilities. SDM model shows that IMR in Indonesia is also influenced by several explanatory variables neighboring districts/cities.

DISCUSSION

Child marriage is a social practice with significant implications for early pregnancy, posing long-term risks to younger mother and the well-being infant (Hossain et al., 2022). Furthermore, it has a positive relationship with IMR across several districts/cities in Indonesia statistically, after accounting for the influence of other variables. This shows that greater percentage of child marriage results in higher IMR. Similarly, Raj & Boehmer (2013) stated that areas with higher rates of child marriage had significantly greater IMR, as young mothers failed to access maternal health services. Trommlerová (2020) explained that mothers who engaged in child marriage experienced a higher incidence of death in the first year of life due to incomplete physical and reproductive maturity, leading to an increased risk of perinatal complications (Ozalp et al., 2003). Mothers who marry at an older age are physically prepared to give birth and take care of healthy infant (Kalipeni, 1993).

Previous research suggested that child marriage increases the incidence of communicable diseases in infant, thereby increasing vulner-

Figure 2
Spatial Cluster Distribution of Child Marriage and IMR, Indonesia 2021



Note : Geoda 1.20 processing results

ability to death. Although some infants may survive, there would be high susceptibility to low birth weight, premature birth, and death (Hossain et al., 2022). Child marriage is closely related to mothers and nutrition, as geographical areas with lower infant nutritional standards tend to experience IMR (Singh et al., 2011). Early maternal age is correlated with poor use of health facilities and experiences of mothers with suboptimal infant feeding. Hossain et al. (2022) also explained that child of married women is significantly less susceptible to diarrhea and cough compared to those born in child marriage.

Spatial Lag

Similarities or differences in characteristics among adjacent districts/cities can trigger an increase or decrease in IMR. The Rho value shows that when IMR in districts/cities adjacent to district i increases by one death per 1000 live births, a significant rise of 0.587 deaths per 1000 live births occurs. Spatial lag coefficient, which has a positive value, correlates with descriptive results using ESDA, where most of districts/cities in Indonesia are included in clusters I and III, namely the high-high and the low-low, respectively. This shows a unidirectional relationship between IMR in districts/cities and other neighboring areas.

Spatial distribution of spatial clusters is shown in Figure 2. The areas in red are districts/cities with a high percentage of child marriage and IMR, falling in the high-high, categories Based on the results, the areas include eastern Indonesia, such as the provinces of North Maluku, West Papua, and Papua, and some districts/cities on the islands of Sulawesi, Sumatra, and Kalimantan. The dark green areas in the figure show low-low clusters, namely districts/cities with a low percentage of child marriage and IMR. These districts/cities included in the low-low cluster are in DKI Jakarta Province, with a significant representation from Central Java, West Java, East Java, and Bali, as well as the islands of Sumatra, Kalimantan, and Sulawesi. Meanwhile, the light green areas show districts/cities with a high percentage of child marriage and IMR, which are categorized in the low or low-high percentages.

Relationship of Other Factors with Infant Mortality

The maternal factor, consisting of women education and LFPR, negatively affects districts/cities IMR in Indonesia. Moreover, the mechanisms by which increased education can lead to reduced infant mortality include timely use of health services, economic benefits, high autonomy, as well as increased status in families and communities (Levine & Rowe 2009). Women education at districts/cities level is also crucial for transmitting good practices in infant care, including using health services (Singh et al., 2011), as shown by the sociocultural practices in society (Ladusingh & Singh, 2006).

Women LFPR plays an essential role in reducing IMR through generated income. This phenomenon is attributed to the significant contribution of female workers to family income, increased purchasing power, and high consumption rate. Therefore, increased female workers are associated with decreased infant mortality because the benefits derived from generated income are more significant compared to the reduced time spent caring for infant (Rosenzweig & Schultz, 1983). Mosley & Chen (1984) stated that income/wealth could support proper basic needs affecting health and survival of infant. The income effect mechanism is by ensuring adequate food and water to support clean living and avoid contamination, good housing conditions, sufficient fuel supply, and access to affordable health services.

Household factors consist of poverty, size, and cooking fuel. The results from SDM regression show a positive relationship between poverty and districts/cities IMR. Gupta et al. (2016) also confirmed the positive relationship between the percentage of households in the lowest wealth quintile and IMR spatially. Furthermore, it was discovered that limited economic resources would affect the inability to meet the health needs of infant (Poerwanto et al., 2003). This is because poverty is associated with low knowledge of disease prevention and difficulty accessing health services, increasing infant mortality (Lawn et al., 2005).

Household size calculated based on the average members has a positive and significant relationship to districts/cities IMR. This result correlated with Barufi et al. (2012), which led to geographic area variations in household size affecting infant mortality. Larger household size increases infant mortality due to the association with competition for economic and health resources (Gupta et al., 2016), influencing the population density of areas. Hathi et al. (2017) explained that greater population density had a higher chance of disease transmission, thereby affecting infant mortality.

Cooking fuel shows a positive and significant relationship with districts/cities IMR, where an increase in the percentage of households using solid fuels such as briquettes, charcoal, and firewood has a high IMR. Similarly, Gouda et al. (2015) explained that areas with a higher percentage of clean fuel use were associated with a decrease in IMR. This is because contaminated fuel is the main predictor of ISPA among infant. Alam et al. (2022) explained that the respiratory system of infant was comparatively weaker, inhaling a higher air volume. When solid fuels are used indoors, it significantly increases the concentration of toxic pollutants in the household and ambient air. This phenomenon increases the incidence of respiratory tract diseases, including acute lower respiratory tract infections, pneumonia, and asthma.

The health factor shows a negative relationship between birth attendants, the number of districts/cities health facilities, and IMR. This shows that a higher percentage of women of childbearing age giving birth safely in a health facility and assisted by competent health workers results in lower districts/cities IMR. According to Das et al. (2021), safe delivery carried out in health facilities and handled by skilled personnel reduces the risk of maternal complications during and after delivery. This is because skilled birth attendants can provide effective obstetric and neonatal care to reduce infant mortality (AIPI, 2013). The number of health facilities will also support the delivery of maternal and child healthcare, capable of reducing IMR in districts/cities. Gupta et al. (2016) also explained the importance of health facilities that served 24 hours, causing a reduction in districts/cities IMR in Indonesia.

This research contributes to producing empirical evidence and enriching the literature on IMR in Indonesia, specifically those associated with child marriage and spatial influences between districts/cities. Additionally, the analysis uses information on household facilities, maternal factors, health services, and health facilities at the district level as control variables to identify factors causing IMR inequality. The results obtained provide valuable input for improving districts/cities with an IMR above the national average to support regional-based government policies in reducing IMR in Indonesia. Meanwhile, the limitations of this research include the inability to account for several factors such as low birth weight, nutrition, and disease as one of the determinants of infant mortality. IMR data used is a conversion of life expectancy at birth due to the unavailability of data at the districts/cities level.

CONCLUSIONS

In conclusion, the inferential statistics in this research showed spatial dependency on districts/cities IMR variable in Indonesia. The results identified SDM as the best model showing that districts/cities IMR in Indonesia was statistically significantly influenced by child marriage. Women education, LFPR, percentage of assisted safe delivery, and the number of health facilities in districts/cities had a negative and significant relationship with districts/cities IMR. Meanwhile, poverty, average family members, and the use of solid fuels for cooking had positive and significant relationships. The SDM showed that IMR in Indonesia was also influenced by several explanatory variables neighboring districts/cities.

The grouping of IMR in Indonesia suggested that the government should prioritize groups of districts/cities with higher rates, specifically in eastern areas. To reduce IMR, strategic development measures are essential, such as building access roads from areas with high to low IMR. Furthermore, there should be a connection between districts/cities with high and low health facilities to facilitate easy access to affordable health services. By identifying the positive relationship, the National Population and Family Planning Board collaborated with the Ministry of Women's Empowerment and Child Protection to conduct socialization of the Genre program in areas with a high percentage of child marriage. This collaborative effort was carried out to prepare youth for family life by understanding the importance of delaying the age of marriage. Additionally, information and technology could be used to carry out massive socialization regarding the importance of increasing the age of marriage.

Further research was recommended to calculate the direct and indirect impacts spatially from the influence of child marriage, access to health services, human capital, and poverty in districts/cities IMR in Indonesia. Additionally, incorporating control variables for child factors including low birth weight, disease, and maternal factors such as birth spacing was highly recommended to enhance the analysis results.

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AUTHORS' CONTRIBUTIONS

Nugrahayu Suryaningrum designed the study, formulated the concept, wrote and reviewed the manuscript, acquired and analyzed the data acquired. Omas B. Samosir and Triasih Djutaharta enrolled participants, reviewed and revised the manuscript. All authors read and approved the final manuscript.

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COMPETING INTERESTS

The authors confirm that all of the text, figures, and tables in the submitted manuscript work are original work created by the authors and that there are no competing professional, financial, or personal interests from other parties.

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