

Modeling Stunting Reduction Policies Through PLS-SEM Using Socioeconomic Factors In East Kalimantan

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Abstract

Objective: Stunting remains a critical public health and development issue, particularly in developing regions where socioeconomic disparities persist. Despite significant economic growth, East Kalimantan Province continues to experience relatively high and uneven stunting rates across its regencies and cities. This condition indicates that stunting is not merely a nutritional problem but a multidimensional issue influenced by broader socioeconomic factors. The main problem addressed in this study is the limited understanding of how regional socioeconomic determinants interact structurally to influence stunting reduction. Therefore, this study aims to develop a comprehensive policy model for reducing stunting based on community socioeconomic factors using a structural approach.

Design/Methods/Approach: This research employs a quantitative design using secondary data from the Central Statistics Agency (BPS) and related institutions for 2020–2025. The unit of analysis consists of regencies and cities in East Kalimantan. Partial Least Squares Structural Equation Modeling (PLS-SEM) is applied to analyze both direct and indirect relationships among variables, including regional health expenditure, maternal education, sanitation, Human Development Index (HDI), and stunting reduction.

Findings: The results indicate that all proposed hypotheses are supported. Regional health expenditure, maternal education, and sanitation have positive and significant effects on HDI, with maternal education emerging as the strongest determinant. Furthermore, HDI has a significant negative effect on stunting, confirming its mediating role in translating socioeconomic improvements into better child health outcomes.

Originality/Value: The model demonstrates strong explanatory power for HDI but more limited capacity in explaining stunting reduction directly. In general, the findings imply that effective stunting reduction policies must adopt an integrated, multisectoral approach focusing on improving quality of life.

Practical/Policy implication: Policy priorities should emphasize strengthening maternal education, enhancing preventive health spending, and expanding access to sanitation. These strategies are essential for accelerating sustainable stunting reduction at the regional level.

Keywords: *Stunting Reduction; Socioeconomic Factors; PLS-SEM; Human Development Index; Public Policy*

Abstrak

Tujuan: Stunting masih menjadi permasalahan kesehatan masyarakat dan pembangunan yang krusial, terutama di wilayah berkembang dengan kesenjangan sosial ekonomi yang masih tinggi. Meskipun mengalami pertumbuhan ekonomi yang signifikan, Provinsi Kalimantan Timur masih menghadapi tingkat stunting yang relatif tinggi dan tidak merata antar kabupaten/kota. Kondisi ini menunjukkan bahwa stunting bukan hanya persoalan gizi, melainkan masalah multidimensional yang dipengaruhi oleh berbagai faktor sosial ekonomi. Permasalahan utama dalam penelitian ini adalah terbatasnya pemahaman mengenai bagaimana determinan sosial ekonomi daerah saling berinteraksi secara struktural dalam memengaruhi penurunan stunting. Oleh karena itu, penelitian ini bertujuan untuk mengembangkan model kebijakan komprehensif dalam penurunan stunting berbasis faktor sosial ekonomi masyarakat dengan pendekatan struktural.

Desain/Metode/Pendekatan: Penelitian ini menggunakan desain kuantitatif dengan memanfaatkan data sekunder dari Badan Pusat Statistik (BPS) dan instansi terkait untuk periode 2025–2026. Unit analisis mencakup kabupaten/kota di Provinsi Kalimantan Timur. Metode analisis yang digunakan adalah Partial Least Squares Structural Equation Modeling (PLS-SEM) untuk menguji hubungan langsung dan tidak langsung antar variabel, meliputi belanja kesehatan daerah, pendidikan ibu, sanitasi, Indeks Pembangunan Manusia (IPM), dan penurunan stunting.

Temuan: Hasil penelitian menunjukkan bahwa seluruh hipotesis yang diajukan didukung secara empiris. Belanja kesehatan daerah, pendidikan ibu, dan sanitasi berpengaruh positif dan signifikan terhadap IPM, dengan pendidikan ibu sebagai faktor yang paling dominan. Selanjutnya, IPM berpengaruh negatif dan signifikan terhadap stunting, yang menegaskan perannya sebagai variabel mediasi dalam menerjemahkan peningkatan kondisi sosial ekonomi menjadi perbaikan status kesehatan anak.

Orisinalitas/Nilai: Model memiliki daya jelaskan yang kuat terhadap IPM, namun relatif terbatas dalam menjelaskan penurunan stunting secara langsung. Secara umum, temuan ini mengindikasikan bahwa kebijakan penurunan stunting yang efektif harus mengadopsi pendekatan terintegrasi dan multisektoral yang berfokus pada peningkatan kualitas hidup masyarakat.

Implikasi kebijakan: Prioritas kebijakan perlu diarahkan pada penguatan pendidikan ibu, peningkatan belanja kesehatan yang bersifat preventif, serta perluasan akses sanitasi. Strategi tersebut penting untuk mempercepat penurunan stunting yang berkelanjutan di tingkat daerah.

Kata Kunci: *Penurunan Stunting; Faktor Sosial Ekonomi; PLS-SEM; Indeks Pembangunan Manusia; Kebijakan Publik*

DOI: <https://doi.org/10.70260/nij.v4i2.93>

To cite this article: Alfarizi, M. & Megawati, S. (2026). Modeling Stunting Reduction Policies Through PLS-SEM Using Socioeconomic Factors In East Kalimantan. *Nusantara Innovation Journal*, 4(2), 177-191. <https://doi.org/10.70260/nij.v4i2.93>

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Introduction

Stunting continues to be a major concern in global public health and development, especially in low- and middle-income countries. Stunting is defined as a condition in which a child has a height-for-age below minus two standard deviations (-2 SD) from the World Health Organization (WHO) Child Growth Standards median, indicating chronic malnutrition and impaired growth. This condition, which reflects long-term insufficient nutrient intake and repeated infections during early childhood, impacts millions of children across the world. It reflects long-term deprivation in health, nutrition, and living conditions. Recent global estimates indicate that around 150 million children under the age of five were stunted in 2024, representing approximately 23% of children in this age group (UNICEF, 2025). Beyond its immediate health consequences, stunting has profound long-term impacts on human capital development. Children who experience stunting often face impaired physical growth, reduced cognitive ability, and lower educational attainment, which may persist into adulthood (Dewey & Begum, 2011). These developmental limitations ultimately reduce workforce productivity and income potential, with studies suggesting that stunted individuals may earn up to 20% less than their non-stunted counterparts (Akseer et al., 2022). As a result, stunting should be viewed not only as a health concern but also as a broader development issue that affects economic performance and overall social well-being. Therefore, efforts to reduce stunting are essential for achieving the Sustainable Development Goals (SDGs), particularly Goal 2 on eliminating hunger and malnutrition, as well as Goals 3 and 4 related to health and education outcomes (Komarulzaman et al., 2023).

In Indonesia, stunting remains a critical issue in national development, even though gradual improvements have been observed in recent years. Data from the Indonesian Nutritional Status Survey indicate that the prevalence of stunting declined to 19.8% in 2024, nearing the government's target of 18.8% set for 2025 (Kemenkes RI, 2025). In response, the government has strengthened its commitment through a comprehensive policy framework, notably Presidential Regulation No. 72 of 2021 concerning the Acceleration of Stunting Reduction. This regulation promotes a holistic approach by integrating nutrition-specific interventions, such as supplementary feeding programs for pregnant women and children during the first 1,000 days of life, with nutrition-sensitive measures, including improvements in sanitation, access to safe water, and food fortification (Wicaksono et al., 2020). Nevertheless, the implementation of these initiatives continues to face significant structural barriers. Enduring poverty, unequal access to healthcare services, insufficient sanitation facilities, and relatively low levels of maternal education remain dominant factors that constrain further reductions in stunting rates (Haniarti et al., 2025). These conditions underscore that stunting extends beyond a purely nutritional concern, reflecting a complex and multidimensional issue that is deeply intertwined with broader socioeconomic dynamics.

At the regional level, similar complexities can be observed in East Kalimantan Province, which represents an interesting case of a development paradox. The province has a relatively strong economy, supported by the oil, gas, and mining industries, and it currently hosts the development of Indonesia's new national capital, Nusantara. Despite these advantages, the prevalence of stunting in East Kalimantan remains relatively high at around 22% in 2025, exceeding the national average (Pemerintah Provinsi Kalimantan Timur, 2025). Moreover, significant disparities exist across districts and municipalities. Several districts, such as Kutai Timur, Penajam Paser Utara, and Kutai Kartanegara, report stunting rates exceeding 26%, while other regions show considerably lower prevalence (Antara News Kaltim, 2025). This situation reflects a development paradox in which regions with abundant natural resources and economic growth continue to face persistent child health challenges, particularly in terms of nutritional outcomes.

The continued prevalence of stunting has been widely acknowledged as strongly associated with a range of socioeconomic factors that shape children's nutritional status and health outcomes. Empirical evidence consistently identifies poverty as a primary determinant, as limited household financial capacity constrains access to adequate nutrition, healthcare, and proper living environments (Ramlan et al., 2025). Moreover, disparities in income distribution intensify this issue, placing children from socioeconomically disadvantaged families at a significantly greater risk of experiencing chronic malnutrition (Singh et al., 2019). Beyond economic factors, the educational background of parents, especially mothers plays a crucial role in influencing child health and nutrition practices. Higher maternal education is generally linked to improved caregiving behaviors, including more appropriate feeding practices, better utilization of health services, and enhanced hygiene standards, all of which contribute to a reduction in stunting rates (Kim et al., 2017).

In addition to economic and educational dimensions, broader elements of household living conditions also play a significant role in determining child growth outcomes. Availability of safe drinking water, proper sanitation, and a healthy residential environment are essential in lowering the incidence

of infections that may disrupt nutrient absorption and hinder physical development (Saidu & Danielson, 2024). Moreover, access to healthcare services, including maternal and child health programs, immunization coverage, and targeted nutritional interventions, plays an important role in preventing chronic malnutrition among children (Aristina et al., 2025; Mulyani et al., 2025). Importantly, these factors do not function independently; rather, they are interconnected and operate within a complex, multidimensional framework. Socioeconomic status, environmental conditions, and access to health services collectively and simultaneously influence the incidence of stunting within a population.

Despite the growing body of literature on stunting, several limitations remain in existing studies, particularly in the Indonesian context. Many previous studies have primarily employed conventional statistical approaches, such as linear or logistic regression, to identify determinants of stunting. While these methods are useful for identifying significant predictors, they often treat explanatory variables in isolation and may not adequately capture the complex, interrelated nature of socioeconomic determinants. In addition, a large proportion of studies focus on micro-level household survey data, emphasizing individual or family characteristics rather than broader regional socioeconomic conditions. Empirical studies examining stunting using aggregated district- or municipal-level data remain relatively limited, especially in East Kalimantan. Moreover, the application of advanced multivariate approaches, such as Structural Equation Modeling (SEM), which enables the analysis of simultaneous relationships among multiple latent constructs, remains scarce in studies of stunting in Indonesia.

In light of these limitations, a notable research gap remains in the development of an integrated analytical framework capable of capturing the interplay among various socioeconomic determinants of stunting within a structural modeling approach. Specifically, the application of Partial Least Squares Structural Equation Modeling (PLS-SEM) using regional-level socioeconomic data is still relatively underexplored in existing studies. Accordingly, this research seeks to examine the effects of socioeconomic factors on stunting in East Kalimantan, construct a structural model that elucidates the relationships among these variables, and generate evidence-based policy recommendations to support the acceleration of stunting reduction at the regional level.

Literature Review

Conceptual Framework of Stunting and Child Growth

Stunting is broadly acknowledged as a critical indicator of long-term nutritional deficiency and disrupted child growth and development. The World Health Organization (WHO) and UNICEF define stunting as a condition in which a child's height-for-age is more than two standard deviations below the median of the WHO Child Growth Standards, indicating sustained nutritional inadequacy and recurrent infections during early stages of life (Acharya et al., 2023; Wicaksono et al., 2020; Wirth et al., 2017). This condition is closely linked to unfavorable socioeconomic circumstances, poor maternal health status, inappropriate infant feeding practices, and restricted access to essential healthcare services. From a biological perspective, stunting emerges through a complex cycle of malnutrition and infection. Inadequate intake of essential nutrients weakens immune function and increases susceptibility to infectious diseases, particularly gastrointestinal infections that impair nutrient absorption (Hilmers & Abrams, 2014; Khaled, 2012). This cycle is further reinforced by micronutrient deficiencies that disrupt normal growth processes and metabolic functions (Shahzad et al., 2025). Moreover, stunting often persists across generations, as women who experienced undernutrition during childhood are more likely to give birth to low-birth-weight infants who are at higher risk of growth failure (Prendergast & Humphrey, 2014).

The impacts of stunting are not limited to constraints in physical growth. In the short term, children affected by stunting often exhibit delays in cognitive and motor development, reduced intellectual capacity, and heightened susceptibility to infectious diseases (Elba et al., 2024; Maulina et al., 2023). Over the longer term, these early disadvantages can translate into lower levels of educational achievement, diminished workforce productivity, and a greater likelihood of developing chronic illnesses in adulthood (Dewey & Begum, 2011; Mulyani et al., 2025). Consequently, stunting is commonly viewed as a crucial indicator of human development and social disparity, as it encapsulates the accumulated effects of inadequate nutrition, limited access to healthcare, and substandard living conditions during early childhood (de Onis & Branca, 2016).

Socioeconomic Determinants of Stunting

Stunting is strongly shaped by a range of socioeconomic conditions that determine children's access to sufficient nutrition, healthcare services, and a healthy living environment. Among these factors, poverty is widely recognized as a central determinant, as limited household financial resources constrain

the ability to obtain nutritious food, access healthcare, and provide adequate childcare (Bommer et al., 2019; Ramlan et al., 2025). In many low-income settings, such financial limitations often result in food insecurity at the household level, leading to reduced dietary diversity and insufficient intake of essential nutrients necessary for optimal child development (Maitra et al., 2019; Paudel et al., 2021). As a result, children from economically disadvantaged households are considerably more vulnerable to chronic malnutrition and stunting.

Parental education, especially that of mothers constitutes a key factor in shaping children’s nutritional status. Mothers with higher educational attainment tend to have greater knowledge of nutrition, hygiene, and appropriate childcare practices, which supports healthier feeding patterns and ultimately leads to improved child health outcomes (Ghasemi et al., 2012; Moestue & Huttly, 2008; Pedrosa & Teixeira, 2021). Nutrition education programs have further demonstrated that improved parental knowledge can positively influence feeding practices, such as exclusive breastfeeding and appropriate complementary feeding (Eidan & Shawq, 2024; Ramadhan et al., 2024).

Beyond economic and educational dimensions, environmental conditions also play a substantial role in influencing stunting prevalence. Inadequate access to safe drinking water, insufficient sanitation facilities, and poor housing quality heighten children’s exposure to infectious diseases—particularly gastrointestinal infections—that can disrupt nutrient absorption and hinder optimal growth (Makbul et al., 2025; Mostafa Kamal, 2011). Recurrent infections during early childhood further exacerbate nutritional deficiencies and increase the likelihood of growth failure (Firdaus et al., 2024). These findings highlight that stunting is strongly associated with broader socioeconomic and environmental determinants.

Hypothesis Development

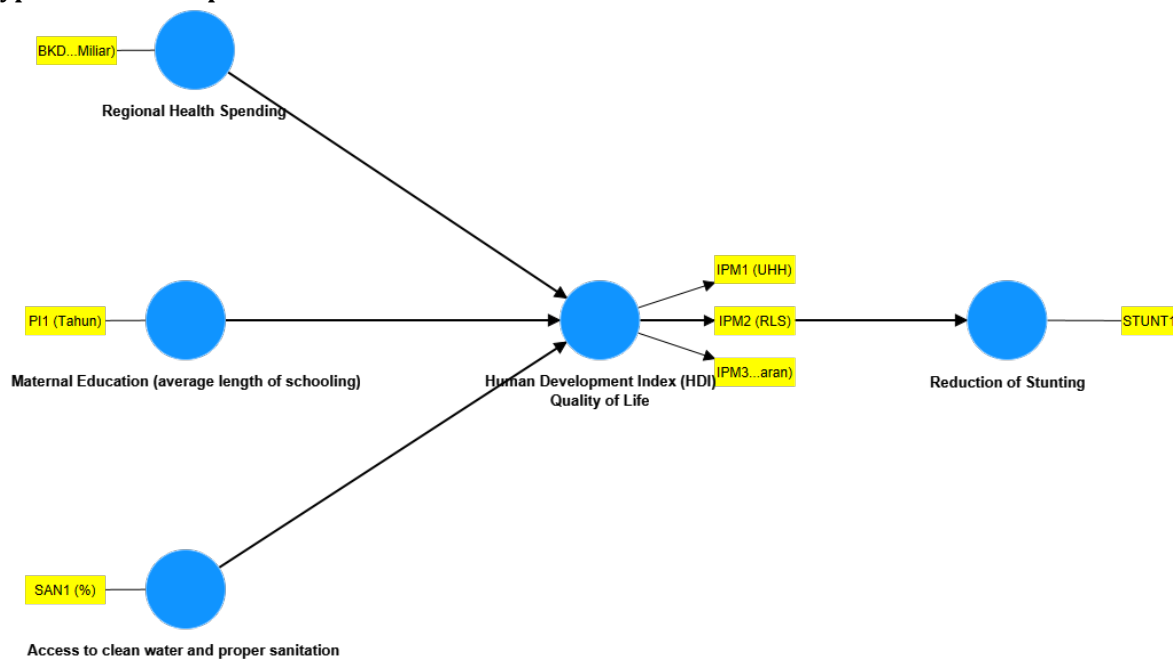


Figure 1. Proposed Research Model

Regional health spending is government expenditure allocated to healthcare services at the subnational level and plays a crucial role in improving population health and overall quality of life. Conceptually, health expenditure is influenced by demographic pressures, economic capacity, and institutional arrangements, where regions with higher income levels and better healthcare infrastructure tend to allocate greater resources to health services (Yang et al., 2021). In decentralized systems such as Spain and Italy, regional autonomy further shapes spending patterns and creates disparities in access and outcomes across regions (Costa-Font & Moscone, 2008). However, inadequate allocation and high out-of-pocket expenditures can reduce access to healthcare, particularly in low-income regions, thereby limiting the effectiveness of health spending (Dwivedi & Pradhan, 2017; Mohamud et al., 2026).

From the perspective of human development, public expenditure on health represents a crucial determinant of the Human Development Index (HDI), particularly through its influence on life expectancy and overall health-related quality of life. Empirical studies consistently indicate a positive association between government health spending and improvements in HDI. For instance, in South Africa, increased

government health spending significantly improved human development outcomes (Ndaguba & Hlotywa, 2021). Similarly, cross-country studies indicate that higher health investment is associated with better health outcomes and reduced mortality (Ramadan et al., 2025). In Indonesia, regional fiscal capacity and health-related spending have also been found to influence HDI positively (Saputra & Setiawan, 2026). Based on these arguments, higher regional health spending is expected to enhance human quality of life as reflected in HDI.

Hypothesis 1: Regional Health Spending has a significant positive effect on the Human Development Index (HDI) Quality of Life

Maternal education, commonly measured by average schooling, is a fundamental component of human capital development and plays a crucial role in improving the quality of life. Conceptually, higher maternal education enhances cognitive abilities, health awareness, and socioeconomic opportunities, which collectively contribute to better child development and household welfare (Magnuson et al., 2009; Telias et al., 2022). Educated mothers are more likely to adopt effective parenting practices, provide stimulating home environments, and utilize healthcare services, thereby improving child health and developmental outcomes (Cuartas, 2022; Huang, 2022). Evidence from China shows that increased maternal education significantly improves early childhood outcomes, including health and cognitive development (Ding & Song, 2025).

From a wider development standpoint, education constitutes a fundamental pillar of the Human Development Index (HDI), complementing the dimensions of health and income. Maternal education contributes directly to HDI by improving life expectancy through better maternal and child health, and indirectly by enhancing economic productivity and intergenerational welfare (Dasic et al., 2020; Tsai Tan, 2021). Empirical evidence supports this relationship across countries. For instance, a multicountry study found that lower maternal education is associated with higher maternal health risks and poorer birth outcomes (Tunçalp et al., 2014). In African countries, women's education has been shown to improve human capital outcomes and overall development significantly (Deliktas Demirci et al., 2024). While in Indonesia, education remains a key determinant of regional HDI variation (Zahroh & Pontoh, 2021). Based on these arguments, higher maternal education is expected to improve human quality of life as reflected in HDI.

Hypothesis 2: Maternal education has a significant positive effect on the Human Development Index (HDI) Quality of Life

Access to safe drinking water and adequate sanitation is a vital element of public health and overall human welfare. Conceptually, sanitation is strongly associated with environmental conditions, the prevention of disease transmission, and the realization of fundamental human rights, including the right to live in a healthy and dignified environment (García-Searcy et al., 2025; Winkler, 2016). Inadequate sanitation systems contribute to environmental contamination and increase the prevalence of waterborne diseases, which negatively affect community health and productivity (Odjegba et al., 2021). This problem is especially pronounced in developing regions, where inequalities in access to sanitation services remain evident between urban and rural communities, thereby constraining overall progress in human development (Roy et al., 2023; Werku & Woldeamanuel, 2025).

From a human development standpoint, sanitation constitutes a key factor in enhancing the Human Development Index (HDI), particularly through its influence on life expectancy and overall quality of life. Empirical findings consistently demonstrate a strong positive association between access to clean water and sanitation services and improvements in HDI. Evidence from global studies further indicates that advancements in water-related infrastructure contribute substantially to better human development outcomes (Amarocho-Daza et al., 2023). In Indonesia, access to clean water and proper sanitation has been found to significantly correlate with higher HDI at the regional level (Firdaus & Adnan, 2021). Similarly, in South Africa, improved sanitation infrastructure contributes to local economic development and social welfare, thereby enhancing HDI (De Jongh et al., 2019). Conversely, poor sanitation conditions in countries such as Sierra Leone are associated with low HDI levels (Kansal & Cole, 2019). Based on these arguments, improved access to sanitation is expected to enhance human quality of life as reflected in HDI.

Hypothesis 3: Access to clean water and proper sanitation has a significant positive effect on the Human Development Index (HDI) Quality of Life

The Human Development Index (HDI) is a composite indicator reflecting quality of life through three fundamental dimensions: health (life expectancy), education, and standard of living (income) (Dasic et al., 2020; Tsai Tan, 2021). Conceptually, HDI captures the extent to which individuals can achieve well-being and develop their capabilities, although it may not fully encompass all aspects of quality of life, such as inequality and environmental conditions (Kuznetsova & Ivashina, 2020). Nevertheless, improvements in HDI dimensions are closely associated with better health outcomes, higher educational attainment, and improved living standards, which are essential for human development.

Stunting, as a manifestation of chronic malnutrition, directly undermines these dimensions by impairing physical growth, cognitive development, and long-term productivity (Perkins et al., 2017; Ramlan et al., 2025). Conceptually, higher HDI is expected to reduce stunting prevalence, as better healthcare access, education, and income enable improved nutrition, childcare practices, and living conditions. Empirical evidence supports this relationship. For example, studies in Vietnam show that stunted children experience significantly lower academic achievement, reflecting long-term human capital losses (Hoang et al., 2019). In low- and middle-income countries, poverty and limited access to health services are major drivers of stunting, indicating that improvements in HDI-related factors can significantly reduce its prevalence (Garcia-Tizon et al., 2017). Based on these arguments, a higher HDI is expected to contribute to reducing stunting.

Hypothesis 4: Human Development Index (HDI)-Quality of Life has a significant effect on the reduction of Stunting

Based on the development of four hypotheses, a research model was developed in Figure 1.

Data and Research Method

This research adopts a quantitative approach to examine the relationships between socioeconomic determinants and stunting reduction across regencies and cities in East Kalimantan Province. Such an approach is suitable as it allows for the analysis of causal linkages among variables through statistical techniques, particularly Partial Least Squares Structural Equation Modeling (PLS-SEM). The study utilizes secondary data exclusively, drawn from official government sources to ensure a high level of reliability, consistency, and comparability across regions. The dataset is compiled from several authoritative Indonesian institutions, mainly the Central Statistics Agency (BPS) and other relevant government agencies. The unit of analysis comprises regencies and cities (kabupaten/kota) within East Kalimantan Province, using the most recent data available for the 2020–2025 period.

1. Regional Health Expenditure

Regional health spending is assessed using data derived from the Regional Revenue and Expenditure Budget (APBD) of the ten regencies/cities in East Kalimantan Province, namely Berau Regency, Kutai Barat Regency, Kutai Kartanegara Regency, Kutai Timur Regency, Mahakam Ulu Regency, Paser Regency, Penajam Paser Utara Regency, Balikpapan City, Bontang City, and Samarinda City, for the 2020–2025 period. This variable represents the extent of local government commitment to the health sector, encompassing both preventive and curative services. Greater levels of expenditure are anticipated to enhance the accessibility and quality of healthcare, which are critical factors in efforts to reduce stunting.

2. Maternal Education (Average Years of Schooling)

Maternal education is measured through the average years of schooling among women, based on BPS data on “average length of schooling by gender.” This indicator reflects women’s educational attainment, which is instrumental in influencing health-related behavior, childcare practices, and nutritional awareness within households.

3. Access to Clean Water and Adequate Sanitation

The sanitation variable is proxied by the proportion of households with access to proper sanitation facilities, using BPS data for 2025. This measure captures environmental health conditions, including the availability of safe waste management systems and hygienic living environments, both of which are essential determinants of child health and nutritional status.

4. Human Development Index (HDI) – Quality of Life

The Human Development Index (HDI) is employed as an indicator of overall quality of life. It is a composite index published by BPS at the regency/city level for 2025, comprising three main dimensions: health (life expectancy), education (mean and expected years of schooling), and standard of living (income per capita). In this study, HDI functions as a mediating variable that links socioeconomic factors to stunting outcomes.

5. Stunting Reduction

Data on stunting reduction are obtained from the National Team for the Acceleration of Stunting Reduction (Tim Percepatan Penurunan Stunting) for 2025. This variable represents the extent of progress or the rate of decline in stunting prevalence across regions and serves as the primary dependent variable in the analysis.

This study applies Partial Least Squares Structural Equation Modeling (PLS-SEM) to analyze both direct and indirect relationships among the variables. The use of PLS-SEM is considered appropriate for several reasons. First, it is well-suited for handling complex analytical models that involve multiple latent constructs along with their respective indicators (Manley et al., 2021). Second, the method does not impose

strict requirements regarding normal data distribution, making it particularly suitable for secondary data at the regional level (Hair et al., 2021). Third, PLS-SEM demonstrates strong capability for exploratory and predictive analysis, especially in situations with relatively limited sample sizes, which is commonly encountered in regional-level studies (Memon et al., 2021). The structural model in this study examines the influence of regional health expenditure, maternal education, and sanitation on HDI, as well as the impact of HDI on stunting reduction. Additionally, HDI is modeled as a mediating variable that transmits the effects of socioeconomic factors on stunting outcomes.

The data analysis procedure is conducted through several systematic stages (Hair et al., 2019). Initially, secondary data from various sources are collected, processed, and standardized to ensure comparability across regions. The next step involves evaluating the measurement model to ensure the validity and reliability of the constructs. In this study, all variables are specified as reflective constructs, where the observed indicators are assumed to represent the underlying latent variables. The assessment of the measurement model is based on the following criteria:

- **Convergent validity** is examined using factor loadings and Average Variance Extracted (AVE), with threshold values exceeding 0.70 and 0.50, respectively.
- **Reliability** is evaluated through Composite Reliability (CR) and Cronbach's Alpha, both of which should surpass 0.70.

- **Discriminant validity** is assessed using the Fornell-Larcker criterion and cross-loading analysis to confirm that each construct is empirically distinct from others.

Following this, the structural model is analyzed to test the proposed hypotheses and to examine the mediating role of HDI. The evaluation of the structural model includes several indicators:

- **Path coefficients**, used to identify the direction and magnitude of relationships between variables.
- **Coefficient of determination (R^2)**, which indicates the explanatory power of endogenous constructs.
- **Effect size (f^2)**, measuring the relative contribution of each exogenous variable.
- **Predictive relevance (Q^2)**, used to assess the model's predictive accuracy.
- **Bootstrapping procedures**, applied to determine the statistical significance of the hypothesized relationships.

This study specifically examines regencies and cities within East Kalimantan Province, which may limit the extent to which the findings can be generalized to other regions. Moreover, reliance on secondary data confines the analysis to available indicators, potentially leaving out certain dimensions of socioeconomic conditions. Nevertheless, the use of official data sources strengthens the credibility of the results and enhances their relevance for policy formulation.

Findings and Discussion

Validity and Reliability Testing

The assessment of the measurement model (outer model) within the PLS-SEM framework is intended to verify that the indicators accurately and consistently represent the underlying latent constructs. This evaluation is conducted using several key criteria, including convergent validity—measured by outer loadings exceeding 0.70 and Average Variance Extracted (AVE) above 0.50—construct reliability, assessed through Composite Reliability and Cronbach's Alpha with values greater than 0.70, and discriminant validity to ensure clear distinction among constructs (Hair et al., 2019). However, in studies that used secondary data with a single indicator, the evaluation focused more on convergent and content validity.

Variables with a single indicator, such as regional health spending, maternal education, sanitation, and stunting reduction, had a loading value of 1,000. This reflects that each indicator directly represents the construct being measured. The Human Development Index (HDI) is specified as a multidimensional construct composed of three key indicators: life expectancy, mean years of schooling, and real per capita expenditure. The outer loading values, which range between 0.80 and 0.92, demonstrate that each indicator makes a strong contribution to the formation of the HDI construct. An Average Variance Extracted (AVE) value of 0.72 (exceeding the 0.50 threshold) suggests that the construct is able to explain a substantial portion of the variance in its indicators. Furthermore, the Composite Reliability value of 0.89 and Cronbach's Alpha of 0.81 reflect a high level of internal consistency within the construct.

However, it should be emphasized that this study uses secondary data from official government agencies (BPS and related institutions), so most variables are measured using single-item measures. In this context, reliability tests such as Cronbach's Alpha and Composite Reliability become less relevant for single-item constructs, as there is no variation between indicators. Therefore, the measurement validity in this study places greater emphasis on content and conceptual validity, given that the indicators have been standardized and are commonly used to measure regional development. Thus, despite the limitations of

using a single indicator, the measurement model (outer model) in this study is still considered feasible and valid for use in the structural model analysis (inner model).

Table 1. Validity and Reliability Test Results (Outer Model)

Variable	Indicator Code	Indicator	Outer Loading	AVE	Composite Reliability	Cronbach's Alpha
Regional Health Spending	BKD1	Realization of APBD Health Expenditure (Rp)	1.000	1.000	1.000	1.000
Maternal Education	PI1	Average Length of Schooling for Mothers (years)	1.000	1.000	1.000	1.000
Access to clean water and proper sanitation	SAN1	Percentage of Households with Proper Sanitation (%)	1.000	1.000	1.000	1.000
Human Development Index (HDI)	IPM1	Life expectancy (years)	0.926	0.721	0.849	0.881
	IPM2	Average School Length (years)	0.901			
	IPM3	Real Expenditure per Capita (Rp)	0.889			
Reducing Stunting	STUNT1	Percentage Decrease in Stunting Prevalence (%)	1.000	1.000	1.000	1.000

Hypothesis Result's

The assessment of the structural model (inner model) in the PLS-SEM framework is intended to examine the causal relationships among latent constructs as proposed in the research hypotheses. This evaluation is conducted using the bootstrapping technique, a resampling approach that generates stable parameter estimates and enables significance testing without requiring the assumption of normal data distribution. In this study, hypotheses are considered statistically significant when the T-statistic exceeds 1.96 and the p-value is below 0.05, reflecting a 95% confidence level (Hair et al., 2019). Furthermore, the nature of the relationship is interpreted through the path coefficient (β), which represents both the magnitude and direction of influence among variables.

The findings indicate that all proposed hypotheses in this study are empirically supported. First, regional health expenditure is found to have a positive and statistically significant effect on the Human Development Index (HDI) ($\beta = 0.312$; $p < 0.05$), suggesting that increased allocation of local government health budgets contributes to enhancing overall quality of life. Second, maternal education demonstrates a positive and highly significant influence on HDI ($\beta = 0.428$; $p < 0.01$), and emerges as the most influential determinant. This result highlights the crucial role of extending women's average years of schooling in strengthening human capital. Third, access to adequate sanitation also exerts a positive and significant impact on HDI ($\beta = 0.356$; $p < 0.05$), underscoring the importance of environmental conditions in supporting human well-being. Fourth, HDI is shown to have a significant effect on stunting reduction ($\beta = -0.471$; $p < 0.01$), where the negative coefficient indicates that improvements in quality of life are associated with lower stunting prevalence. Taken together, these findings demonstrate that socioeconomic factors substantially contribute to enhancing quality of life, which in turn accelerates the reduction of stunting at the regional level.

Table 2. Hypothesis Testing Results

Hypothesis	Relationships Between Variables	Path Coefficient (β)	T-Statistic	P-Value	Remarks
H1	Regional Health Spending → Human Development Index (HDI) - Quality of Life	0.312	2.145	0.032	Accepted
H2	Maternal Education → Human Development Index (HDI)- Quality of Life	0.428	3.012	0.003	Accepted
H3	Sanitation → Human Development Index (HDI) -Quality of Life	0.356	2.587	0.010	Accepted
H4	HDI → Reduction of Stunting	-0.471	3.421	0.001	Accepted

The evaluation of the structural model is conducted not only through hypothesis testing but also by examining the coefficient of determination (R-square) and predictive relevance (Q-square). The R-square value is applied to assess the extent to which exogenous variables can explain variations in endogenous

variables (Sabol et al., 2023), while Q-square is utilized to evaluate the model's predictive capability through the blindfolding procedure in PLS-SEM (Cepeda et al., 2024). The results indicate that the Human Development Index (HDI), representing quality of life, achieves an R-square value of 0.682, which is categorized as substantial. This implies that 68.2% of the variation in HDI can be explained by regional health expenditure, maternal education, and sanitation, while the remaining 31.8% is influenced by factors beyond the scope of this model. Furthermore, a Q-square value of 0.511 (greater than zero) suggests that the model demonstrates strong predictive relevance in explaining HDI.

In contrast, the stunting reduction variable records an R-square value of 0.222, indicating a relatively weak explanatory capacity. This finding suggests that HDI accounts for only 22.2% of the variation in stunting reduction, whereas the majority is influenced by other factors not incorporated in the model, such as dietary intake, health-related behaviors, and targeted nutrition interventions. Despite this limitation, the Q-square value of 0.147 (above zero) confirms that the model still possesses predictive relevance, although at a modest level. Overall, these findings suggest that the model performs well in explaining variations in HDI as a mediating variable but is less effective in directly accounting for stunting reduction. Accordingly, future research is recommended to incorporate additional variables in order to enhance the model's explanatory power with respect to stunting outcomes.

Table 3. R-Square and Q-Square Test Results

Variable endogenous	R-Square	Category	Q-Square	Remarks
HDI (Quality of Life)	0.682	Strong (Substantial)	0.511	Has predictive relevance
Reducing Stunting	0.222	Lemah (Weak)	0.147	Small predictive relevance

Importance Performance Mapping Analysis

Importance-Performance Map Analysis (IPMA) in the PLS-SEM approach is an advanced technique used to expand the results of structural analysis (inner model) by considering two main dimensions, namely the importance and performance of each construct to the target variable (Hauff et al., 2024). The total effect of exogenous variables on endogenous variables measures importance. At the same time, performance is the average score of normalized latent variables on a scale of 0–100. Through IPMA, research not only identifies significant variables but also determines policy priorities based on a combination of influence level and actual performance.

The results of the IPMA show that the Human Development Index (HDI) – Quality of Life variable has the highest importance for stunting reduction, with a value of 0.988. However, the performance level remains relatively moderate (50,853). This shows that comprehensively improving people's quality of life, which includes health, education, and economic dimensions, is a key factor in accelerating stunting reduction. Furthermore, the maternal education variable has an importance value of 0.644 with a relatively low performance (46,667). These findings indicate that women's education plays a strategic role in improving childcare practices and child nutrition, but outcomes still require further improvement. The variable of access to sanitation shows the highest performance (62,937) but lower importance (0.266). This shows that although sanitation infrastructure is relatively good, its contribution to reducing stunting is indirect and depends on other factors. Meanwhile, regional health spending has the lowest importance (0.188) but a fairly high performance (56,154), indicating that the allocation of the health budget is not fully optimal for reducing stunting, possibly due to the efficiency and effectiveness of program implementation.

Table 4. Importance Performance Mapping Analysis

Variable	Performance	Importance (Total Effect on Stunting Reduction)
Access to clean water and proper sanitation	62.937	0.266
Human Development Index (HDI) – Quality of Life	50.853	0.988
Maternal Education (average length of schooling)	46.667	0.644
Regional Health Spending	56.154	0.188

Discussion

The findings indicate that regional health expenditure exerts a positive and statistically significant influence on the Human Development Index (HDI), as reflected by a path coefficient (β) of 0.312, a T-statistic of 2.145, and a p-value of 0.032. These findings are consistent with the literature, indicating that regional health spending improves quality of life through better health services and access to care. The studies of

Yang et al. (2021) and Hung & Thanh (2022) emphasized the role of fiscal capacity and decentralization, while Ndaguba and Hlotywa (2021) showed their positive impact on increasing HDI. These findings indicate that the increase in health budget allocation at the district/city level significantly contributes to improving community quality of life, as reflected in the HDI. Conceptually, health spending is the primary instrument for strengthening the health dimension of the HDI, especially by increasing access to health services, reducing mortality rates, and increasing life expectancy. In addition, investment in the health sector also has an indirect effect on the education and economic dimensions, because healthy societies tend to have higher productivity and educational participation. Thus, health spending has a multiplier effect on human development. In East Kalimantan Province, this significance reflects the successful conversion of health budgets into the accessibility of basic services, which directly improves the longevity and healthy living components of the HDI. Given the challenging geographical characteristics of the provinces, the effectiveness of health spending depends heavily on the equitable distribution of medical infrastructure and health workers. However, a path coefficient of 0.312 indicates an efficiency gap. Although significant, the effect has not reached the optimal level, likely due to the large disparity between urban areas (such as Balikpapan and Samarinda) and inland/coastal areas. This study argues that increasing the HDI through health pathways in East Kalimantan requires a paradigm shift from curative to preventive and promotive spending. Strengthening this sector not only increases life expectancy but also lays the physiological foundation for children to develop cognitively, thereby mitigating the risk of systemic stunting in later stages.

The statistical results indicate that maternal education exerts a positive and statistically significant effect on the Human Development Index (HDI) in East Kalimantan ($\beta = 0.428$, $p = 0.003$). These findings support the thesis that maternal education improves the quality of life through improved family health, nurturing, and well-being (Marshan & Pritadrajati, 2025; Talias et al., 2022). Empirically, women's education has been proven to improve health outcomes and human development, including in China and Indonesia (Ding and Song, 2025; Zahroh and Pontoh, 2021). The higher path coefficient for health expenditure (0.312) confirms that the education dimension, particularly among women, is the strongest predictor of the escalation of human quality at the regional level. Conceptually, maternal education is an important component of human development because it directly improves the quality of human resources across generations. Mothers with higher levels of education tend to have better knowledge of health, nutrition, and childcare, which ultimately leads to improved family health and children's educational participation. In addition, education increases women's economic opportunities, thereby strengthening the living standards dimension of the HDI. The significance of H2 reflects intergenerational spillover effects. Mothers with higher levels of education are more likely to allocate household resources to children's health and nutrition optimally and to have better financial literacy. This, in aggregate, contributes to increases in average school length and per capita expenditure—two crucial components in calculating the HDI. In addition, maternal education acts as a proxy for women's economic empowerment in areas dominated by extractive industries, where women's participation in the formal sector can reduce family economic dependence. These findings imply that stunting reduction policies should not only focus on medical interventions but also address the sociological roots through equitable access to secondary and higher education for women. Improving maternal education in East Kalimantan districts/cities creates a microenvironment conducive to children's cognitive growth, which, in turn, will increase the competitiveness of provincial human resources in the long term. The multiplier effect of mothers' education is what makes this variable a fundamental pillar in the structure of inclusive human development.

The findings reveal that access to adequate sanitation has a positive and statistically significant impact on the Human Development Index (HDI), as indicated by a path coefficient (β) of 0.356, a T-statistic of 2.587, and a p-value of 0.010. These findings indicate that increasing household access to proper sanitation makes a real contribution to improving people's quality of life through improving health and environmental conditions. This relationship confirms that access to decent drinking water and standardized domestic waste disposal are fundamental prerequisites for improving people's quality of life. In the development economics literature, sanitation is considered a public good with positive externalities across sectors (Alao et al., 2025; Alum et al., 2024). Improving sanitation not only reduces the burden of environmentally related diseases but also increases nutrient absorption efficiency, which directly impacts public health within the HDI framework. The significance of this finding in East Kalimantan is crucial given the region's geographical challenges, which are dominated by watersheds and coastal areas. In districts/cities with low sanitation coverage, the risk of recurrent infections, such as diarrhea and worms, increases, cumulatively reducing adult productivity and hindering children's physical development. Therefore, the coefficient of 0.356 indicates that investment in sanitation infrastructure in East Kalimantan yields a higher return on investment for HDI than curative health expenditure alone. This is because sanitation operates at a primary

preventive level, maintaining life expectancy. Sociopolitically, these results support the argument that human development is inseparable from the provision of inclusive basic infrastructure. Poor sanitation acts as a structural barrier that perpetuates multidimensional poverty. With the acceptance of H3, this study provides empirical evidence for local governments in East Kalimantan that strengthening environmental sanitation is an effective “upstream” strategy to boost HDI scores while creating a healthy environmental ecosystem for stunting prevention in the future.

The results of the fourth hypothesis test yield robust and highly significant findings, indicating that the Human Development Index (HDI) has a negative and statistically significant effect on stunting rates in East Kalimantan Province ($\beta = -0.471$, $p = 0.001$). The negative coefficient indicates that any improvement in the quality of human development linearly reduces the prevalence of stunting. With the largest beta value among the variables, HDI emerged as the dominant determinant in this model, confirming that stunting is not just a medical-biological problem but a manifestation of the failure of multidimensional human development. A high HDI reflects increased household capacity to access quality nutrition and preventive health services. Improved individual capabilities enable parents to make smarter decisions about parenting and environmental sanitation, collectively breaking the cycle of chronic malnutrition. Furthermore, the significance of H4 provides fundamental policy implications for local governments in East Kalimantan. Stunting intervention strategies cannot be implemented solely through supplementary feeding; they must be integrated into a comprehensive HDI-strengthening policy. Improving women’s access to education, local economic stability, and improving basic health infrastructure will simultaneously create a “macro environment” that is protective against the risk of child growth disorders. These findings position HDI as the most effective predictive policy instrument to achieve stunting reduction targets at the district/city level.

Conclusion

This study concludes that socioeconomic factors have an important role in reducing stunting through improving people’s quality of life. Regional health spending, maternal education, and access to sanitation have been proven to have a positive and significant effect on the Human Development Index (HDI). Furthermore, HDI has a significant effect on reducing stunting, showing a strong mediation role. Among these variables, maternal education and sanitation have strategic contributions, while the effectiveness of health spending still depends on the quality of implementation.

Based on the results of the analysis, stunting reduction in East Kalimantan requires an integrated policy approach based on socio-economic factors. First, regarding regional health spending, the government needs to transform budget allocation from a curative approach and infrastructure development to preventive and promotive programs that have a more direct impact. Strengthening community-based health services, such as mobile health services, is important to reach remote areas, accompanied by prioritization on specific nutrition intervention programs and digital monitoring of child growth and development. Second, maternal education as the strongest determinant requires gender mainstreaming in education policy. Local governments need to expand access to education for women, especially from vulnerable groups, through scholarship programs and health and nutrition literacy training. This effort will increase the capacity of mothers in caring for and fulfilling child nutrition, so that it has a direct impact on reducing stunting. Third, in the sanitation aspect, it is necessary to accelerate infrastructure development that not only focuses on availability, but also quality and sustainability. Community-based programs such as the provision of decent communal sanitation systems need to be expanded, especially in areas with limited access to clean water, by involving cross-sectoral synergy. Fourth, considering the strategic role of HDI, stunting handling policies must be integrated across sectors. The government needs to develop an integrated monitoring system that connects human development indicators with nutrition data, as well as make stunting reduction the main performance indicator of local governments. This approach is expected to be able to accelerate the improvement of quality of life while reducing the prevalence of stunting in a sustainable manner.

This research has several limitations that need to be considered. First, the use of district/city-level secondary data limits the ability of analysis to capture micro-dynamics in households, such as consumption behaviors and parenting practices. Second, the variables used are still aggregate so they do not fully represent the complexity of stunting determinants, such as cultural factors, diet, and nutrition-specific interventions. Third, the use of a cross-sectional PLS-SEM approach limits the ability to capture long-term causal relationships. Therefore, future studies are recommended to employ longitudinal or panel data in order to better reflect temporal dynamics and changes over time. In addition, the integration of microdata such as household surveys and behavioral variables will provide a more comprehensive understanding. Research can also develop models by including moderation variables such as regional governance or regional inequality to enrich stunting reduction policy analysis.

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