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A Structural Equation Modeling-Based Maternal Mortality Prediction Model with Three Levels of Determinants

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Abstract Maternal mortality is an important indicator of national health. The Sustainable Development Goals (SDGs) target reducing maternal mortality to a maximum of 70 per 100,000 live births by 2030. No country can accept a doubling of the maternal mortality rate. Maternal mortality is caused by distant, intermediate, and immediate factors. Given the high rate, the Lampung Health Service prioritizes addressing maternal mortality. This study evaluates the factors that contribute to maternal mortality as variables that influence its prevalence and analyzes the equation model in Lampung, Indonesia. This study was conducted in Lampung Province, using analytical descriptive method with case-control approach. The population was divided into case and control groups, using a complete and proportional randomly selected sample from 87 community health centers in 90 sub-districts in Lampung. Each case and control group consisted of 97 samples. Distant determinants included socioeconomic and environmental health issues; intermediate determinants included maternal health status, access to health services, and use of those services; while immediate determinants were pregnancy complications. In this study, SPSS (Statistical Package for the Social Sciences) and PLS-SEM (Partial Least Squares - Structural Equation Modeling) were applied for data analysis. The results of the analysis identified 11 path hypotheses, with 7 of them having a significant effect on maternal mortality. In Lampung Province, socioeconomic factors, environmental health, utilization and access to health services, maternal health conditions, and pregnancy complications contributed to maternal mortality. Socioeconomic factors and access to health services contributed 97.79% to maternal mortality. The findings suggest the importance of hand hygiene promotion, job creation in the community, diversification of food choices, improved access to delivery facilities, and implementation of better health practices. In addition, prevention, health promotion and treatment of conditions such as preeclampsia/eclampsia need to be prioritized.

Keywords Maternal Mortality, Determinants, Structural Equation Modeling, Socioeconomics

1. Introduction

Maternal mortality is a significant global health issue in both developing and developed countries. Maternal mortality occurs during or after pregnancy. Problems or improper management during pregnancy contribute to

maternal mortality [1]. The maternal mortality rate in low-income countries is as high as 94%. Developing countries experience a maternal mortality rate of 462 per 100,000 live births, whereas in developed countries, this rate is reduced to only 11 per 100,000 live births. According to the World Health Organization (WHO), the risk of death for pregnant women in high-income countries is 1 in 5400, compared to 1 in 45 in low-income countries. Thus, the risk of maternal mortality and pregnancy complications is much higher in developing countries [2].

The number of maternal mortalities is a key indicator to assess the quality of a country's health and well-being. The Sustainable Development Goals (SDGs) seek to achieve a global target of a maximum maternal mortality of 70 per 100,000 live births, with the expectation that no country will have a maternal mortality rate more than double the global average [4]. WHO data from 2020 noted that there are around 800 maternal mortalities every day in low-income countries, indicating a gap in access to quality health services. This gap is particularly pronounced between upper and lower economic groups. For this reason, more intensive efforts are needed to reduce maternal mortality in accordance with the established goals.

Indonesia, as a developing country, has a maternal mortality rate of 189 per 100,000 live births in 2020 [5]. Based on data from the United Nations Development Programs (2015), the risk of maternal mortality in Indonesia is 1 in 65, with a total of 20,000 maternal mortalities out of 5,000,000 births. To achieve the Sustainable Development Goals (SDGs) by 2030, the Indonesian government needs to take big and serious steps [6,7,8]. Efforts have been made to identify factors that contribute to maternal mortality, which is a complex problem influenced by various immediate, intermediate, and distant determinants [9]. Alvarez [10] and Rogo [11] emphasized that individual and community factors play a direct and indirect role in influencing maternal mortality. Complications during pregnancy are identified as immediate determinants that determine maternal mortality. Meanwhile, intermediate determinants affect health through their impact on immediate determinants. Distant determinants, which include demographic, cultural, economic, political, and socioeconomic aspects, also play a role in determining the conditions that contribute to maternal mortality [9,12,13].

Socioeconomics includes elements such as education, occupation, income, ethnicity, and social class, all of which contribute to the formation of social stratification and hierarchy. This stratification results in health disparities and problems [14,15,16]. There is evidence to suggest that maternal mortality is generally higher among individuals with low to middle socioeconomic status [17,18]. People from these groups tend to face environmental conditions that are not favorable to health, such as limited access to clean water, sanitation, and hygiene. Research shows that poor sanitation increases the risk of infection and health complications during pregnancy by 2.38 times [21]. Therefore, improving water quality and sanitation is essential and can significantly reduce maternal mortality [22,23,13].

Lampung Province experiences unpredictable annual fluctuations in the frequency of maternal mortality. In 2018, the maternal mortality rate reached 148 per 100,000 live births [24], with the main causes including bleeding (27.1%), preeclampsia/eclampsia (22.1%), and other factors (30.2%). Based on data from Statistics Indonesia (2019b), Lampung Province ranks second to bottom in the availability of clean water sources, with only 56.78% of households having access to adequate drinking water. In addition, Lampung is also ranked fourth lowest for ownership of proper sanitation facilities, at 52.48% [25]. This suggests a possible correlation between various factors that together contribute to the direct, intermediate, and distant causes of maternal mortality in the region.

Determinants of maternal mortality are latent factors that cannot be measured directly, but through indicators. The use of regular multiple regression on latent variables can cause problems in parameter measurement. If indicators of the latent variable are used without including the latent variable itself, there will be errors in parameter measurement [26]. Therefore, the development of multivariate statistical analytic approaches is essential to enable researchers to examine complex interactions between variables, both recursive and non-recursive, to produce a more unified model. This analysis uses Structural Equation Modeling (SEM) [27,28], a statistical technique that facilitates simultaneous modeling of linear relationships between observed variables (indicators) and latent variables, which are variables that cannot be measured directly [29]. Thus, this study aims to analyze the three determinants of maternal mortality and develop a model to reduce the high maternal mortality rate.

2. Materials and Methods

Data for this study were collected from various regencies and cities in Lampung Province. The method used was a descriptive case-control design, in which the cause-and-effect relationship was investigated through a comparison between the case group and the control group based on their level of exposure. To examine the influence of risk factors on both groups, a retrospective study was conducted.

The study sample consisted of a case group of 97 people and a control group of 97 people. In the context of Lampung Province in 2018, this study involved 90 sub-districts and 87 community health centers. A complete sampling method was applied to select the sample in the case group. The inclusion criteria included: (1) the occurrence of maternal death during pregnancy, delivery, or postpartum; (2) availability of address in health service records. Meanwhile, the exclusion criteria were aimed at respondents who did not comply with the predetermined

research procedures.

For the control group, this study used proportionate random sampling approach involving 97 people who met the inclusion criteria. The inclusion criteria were: (1) pregnant women without complications during pregnancy, labor, or the postpartum period; and (2) pregnant women who lived in the same geographical area as the case group. Pregnant women who faced problems during pregnancy, labor, or postpartum, as well as those who showed unwillingness to participate in the study, were excluded. Figure 1 presents the research flow for each variable in the established conceptual framework.

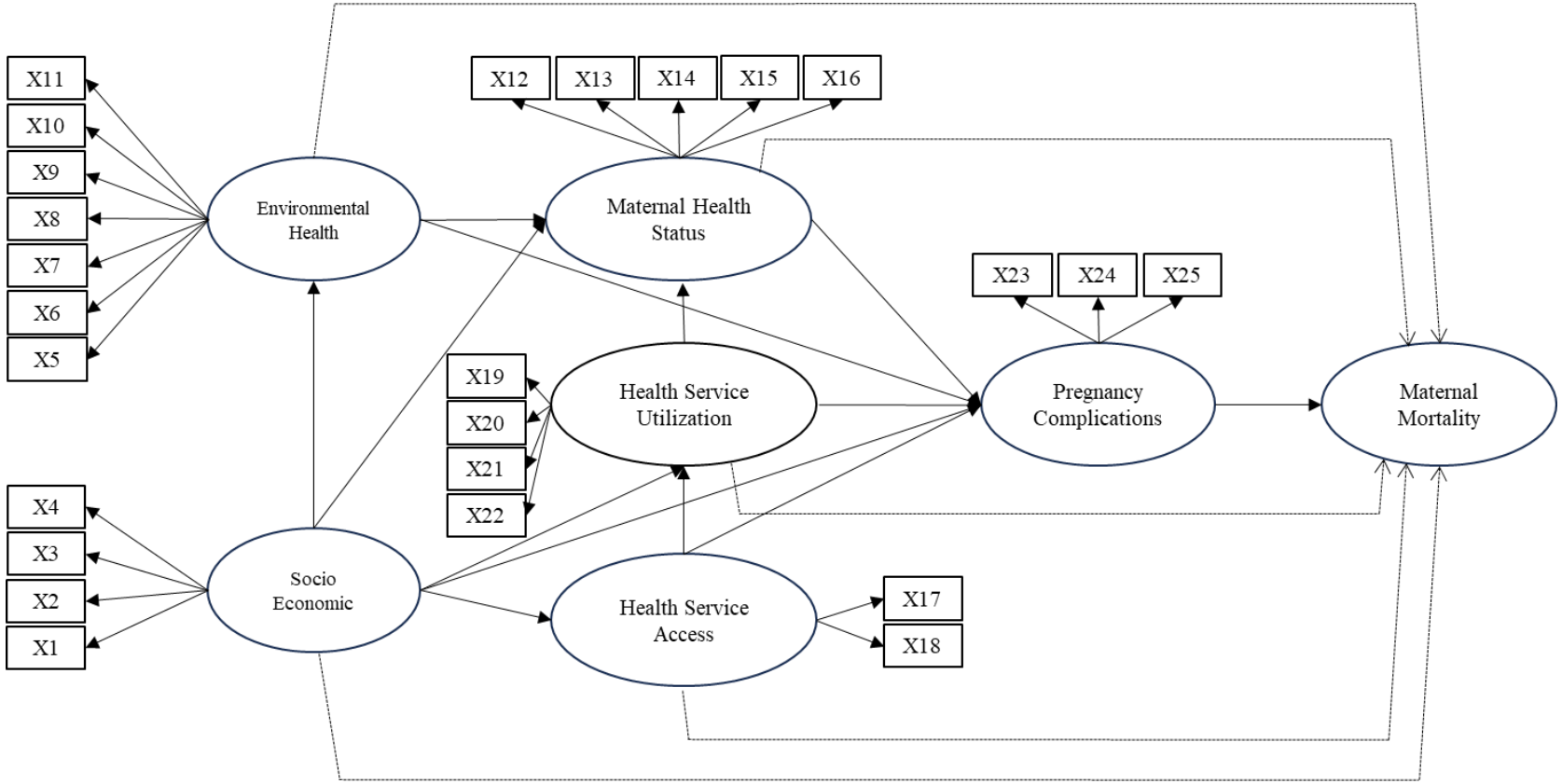

Figure 1. Conceptual framework of research variables. X1: education, X2: employment, X3: family income, X4: social class, X5: accessibility of clean water, X6: elements contained in water, X7: healthy toilet behavior, X8: hand washing behavior, X9: drinking water and food management, X10: waste management, X11: household liquid waste management, X12: adequate food budget, X13: food diversity, X14: weight gain during pregnancy, X15: upper arm circumference, X16: anemia status, X17: ownership of means of transportation, X18: distance to health services, X19: antenatal care pregnancy check-up, X20: pregnant women's class, X21: maternity facilities, X22: birth attendant, X23: bleeding, X24: preeclampsia/eclampsia, X25: infection, Y1: maternal mortality, X: exogenous variable, Y: endogenous variable.

Endogenous variables (η) are variables that are determined by at least one equation in the model, while in the other equations, they are treated as independent variables. In the SEM framework, endogenous variables are represented by arrows pointing to them. Indicators of exogenous variables are described as follows.

The nutritional status of pregnant women has a direct effect on their health condition. Nutritional difficulties play an important role in maternal and fetal health. Evaluating food safety at the household level helps prevent the fatal effects of under- or over-nutrition. Indicators include food budget adequacy, food diversity (very severe, severe, moderate, mild, safe), weight gain, and upper arm circumference [30,31].

Access to health services is measured by assessing indicators such as the availability of transportation infrastructure that can reach health facilities and the distance to these facilities [32,33,34]. Measurement indicators included ownership of transportation facilities (not available, available not privately owned, available privately owned 2-wheeled vehicles, available privately owned 2- and 4-wheeled vehicles) and distance of residence to health services (very far >5km, far 4km, medium 3km, close 2km, very close 1km).

Health service utilization refers to an individual's habit of using available health services to improve maternal health during pregnancy. Indicators used to prevent complications during pregnancy, childbirth, and the postpartum period include frequency of antenatal care (ANC) check-ups (none, once, twice, three times, four times), participation in pregnant women's classes (none, attended once, attended twice, served 3-4 times, served more than 4 times), place of delivery (home with complications, home without complications, midwife-assisted with complications, midwife-assisted without complications, community health center/high school), and presence of birth attendants (Traditional Birth Attendant (TBA), TBA accompanied by midwife, midwife, doctor and midwife, obstetrician (Sp. OG)) [35].

Pregnancy complications encompass obstetric illnesses that occur before or during pregnancy, potentially worsening the condition of the pregnancy [12,36]. This study measured various indicators of pregnancy complications, including different types of bleeding events (requiring varying levels of transfusions), preeclampsia/eclampsia (encompassing both severe and mild cases), and infections (such as septicemia and urinary tract infections).

Exogenous variables (ξ) are those that consistently show up as independent variables in each and every model equation. In SEM (Structural Equation Modelling), exogenous variables are represented by arrows that originate from these variables and point towards endogenous variables. The indicators for exogenous factors are described as follows.

Socioeconomics refers to the amalgamation of social, economic, political, cultural, and environmental factors that give rise to disparities in societal levels. The social determinants are measured using indicators such as education (level of schooling completed), employment (type of work and ability to create jobs), income (amount earned), and social class (socioeconomic status) [37,14].

The assessment of environmental health is determined by evaluating the quality of water and the level of sanitation in households. Sanitation indicators involve various factors such as the availability of clean water (including the adequacy of clean water sources), water quality (ranging from pollution in four elements to no pollution), adherence to proper latrine usage, hand washing practices (measured by the ownership of hand washing facilities and the implementation of hand washing habits), management of drinking water and food hygiene, waste management (including whether it is properly managed, utilized, or ignored), and the handling of household liquid waste.

Data analysis comprises three main types: univariate, bivariate, and multivariate analysis. Univariate analysis aims to illustrate the characteristics of each indicator by presenting a frequency distribution based on percentages and proportions. Bivariate analysis aims to establish correlations between social determinants, sanitation, environment, and risk factors with the incidence of maternal mortality. The study utilized multivariate analysis through SEM using SmartPLS version 4. The objective of this investigation was to assess the impact of social determinants, sanitation, environment, and risk factors on maternal mortality incidence and to construct a predictive model. At this level, analysis is conducted utilizing measurement models and structural models. The criteria for evaluating the measurement model include assessing the absolute fit indices (chi square statistics/X2 $\leqslant$ 0.05, goodness of fit index/GFI $\geqslant$ 0.90, root mean square error of approximation/RMSEA $\leqslant$ 0.80), evaluating the incremental fit indices (normal fit index/NFI $\geqslant$ 0.90, comparative fit index/CFI $\geqslant$ 0.90), and considering the parsimonious fit indices (root mean square error of approximation/RMSEA <0.05, Akaike information criterion/AIC, expected cross validation index/ECVI, Hoetler value >200). The structural model comprises two stages: model specification and SIMPLIS program generation. Subsequently, the SIMPLIS program is executed, and its output is analyzed, potentially leading to model respecification. Respecification occurs when there are problematic estimations, inadequate model validity, insufficient overall model fit, or poor model reliability.

This study received ethical clearance from the Faculty of Medicine, Universitas Lampung. All participants in this study were approached on a voluntary basis and provided with sufficient information during the interview and observation stages.

3. Results

Bivariate analysis involves six variables in total. As depicted in Table 1, each variable comprises several indicators. The analysis reveals that socioeconomic factors (education, income), maternal health status (adequacy of food budget, food diversity, anemia status), health-care utilization (access to maternity facilities, attendance by a birth attendant), and pregnancy complications (hemorrhage, preeclampsia/eclampsia) impact maternal mortality. Limited access to healthcare services is influenced by socioeconomic factors, leading to a decline in maternal health outcomes. The risk of maternal mortality escalates with lower levels of education and household income.

Table 1. Univariate and bivariate analysis of variables influencing maternal mortality (n = 97 on each variable)

Variables	The most cases in category	The majority of cases (%)	*P*-Value
Socioeconomic			
Education	Completed secondary education	37.11	0,013
Employment	Owns a business and works infrequently	46.39	0,151
Income	1.000.000 - 1.500.000 rupiah	60.82	0,014
Social class	Middle class	62.89	0,531
Environmental health			
Clean water accessibility	Simply digging a lip-shaped well is adequate	69.07	0,123
Elemental content	Water is contaminated with 2 chemicals	37.11	0,426
Elemental content	Septic tank-free gooseneck and private latrine	30.93	0,159
Hand washing	Maintain hand washing facilities yet rarely wash hands.	49.48	0,506
Drinking water and food management	Water and food are untreated, and practices of sanitary hygiene are infrequent	61.86	0,700
Waste management	Waste is both controlled and unmanaged	34.02	0,335
Household waste management	Channel-open	64.95	0,222
Maternal health status			
Food budget adequacy	510.000 - 700.000 rupiah	42.27	0,002
Food diversity	The highest food security rate	36.08	0,010
Weight gain during pregnancy	Normal	30.93	0,535
Upper-arm circumference	Normal (90 - 100%)	39.18	0,489
Anemic status	Moderate anemia (7-8gr%)	35.05	0,050
Health service access			
Transportation ownership	Private 2-wheelers are available	75.26	0,563
Distance from healthcare facilities	Distance: (< 3 km)	57.73	0,741
Health service utilization			
Antenatal care (ANC)	Two times	32.99	0,195
Pregnant mother class	Twice attended pregnancy classes	61.86	0,865
Maternity facilities	Midwife with issues	50.52	0,096
Birth attendant	A midwife	49.48	0,015
Pregnancy complications			
Hemorrhage	Previous hemorrhage with 1 kolf transfusion	40.20	0,038
Preeclampsia/eclampsia	Severe preeclampsia	33.00	0,002
Infection	Premature rupture of membranes (PROM)	42.30	0,254

HTMT, also known as Heterotrait-Monotrait Ratio, is a quantitative measure employed in the examination of convergent and discriminant validity. HTMT values are employed to assess the discriminant validity between constructs in SEM study. An optimal HTMT value should be below 0.9. HTMT is employed to quantify the impact of measurement error in SEM analysis. When the HTMT ratio of correlations exceeds 0.9, it indicates a high probability of substantial measurement error. Therefore, it is crucial to assess the HTMT for each construct or variable included in the study [27].

HTMT ensures the distinctiveness of the constructs assessed in the model, contributing to their reliability and the accuracy of the obtained results [27,28]. The HTMT values for each construct in this investigation exceed 0.9, indicating high precision and absence of measurement error (Table 2).

Figure 2 depicts the final structural model, illustrating the relationships between the construct variables and maternal mortality. The p-value associated with each path indicates the significance level of the influence between the construct variables. The path analysis assesses the extent of exogenous variable influence on various endogenous variables within the model, elucidating causal relationships between variables, path coefficients, and the significance of model paths. Path coefficients denote the strength of the impact of the exogenous variable on the endogenous variable, while path significance indicates statistically meaningful effects.

Significant results are denoted by a p-value < 0.05 ($\alpha < 0.05$). Positive path coefficients indicate a unidirectional link between exogenous and endogenous factors, while negative coefficients suggest opposing relationships between external and endogenous factors. According to existing literature, socioeconomic status is identified as a distant determinant that significantly contributes to maternal mortality, alongside other relevant variables. Therefore, socioeconomic variables are seen to influence maternal mortality outcomes. The operational route analysis in Figure 2 revealed that 7 out of 11 pathways had a significant impact on maternal mortality (refer to Table 3 for details).

Table 2. HTMT value (*Discriminant Validity*)

Variable	Health Service Access	Maternal Mortality	Environmental Health	Pregnancy Complications	Health Service Utilization	Socioeconomic
Maternal Mortality	0.127					
Environmental Health	0.800	0.139				
Pregnancy Complications	0.727	0.027	0.719			
Health Service Utilization	0.777	0.192	0.790	0.796		
Socioeconomic	0.872	0.174	0.890	0.751	0.763	
Maternal Health Status	0.871	0.098	0.893	0.899	0.651	0.739

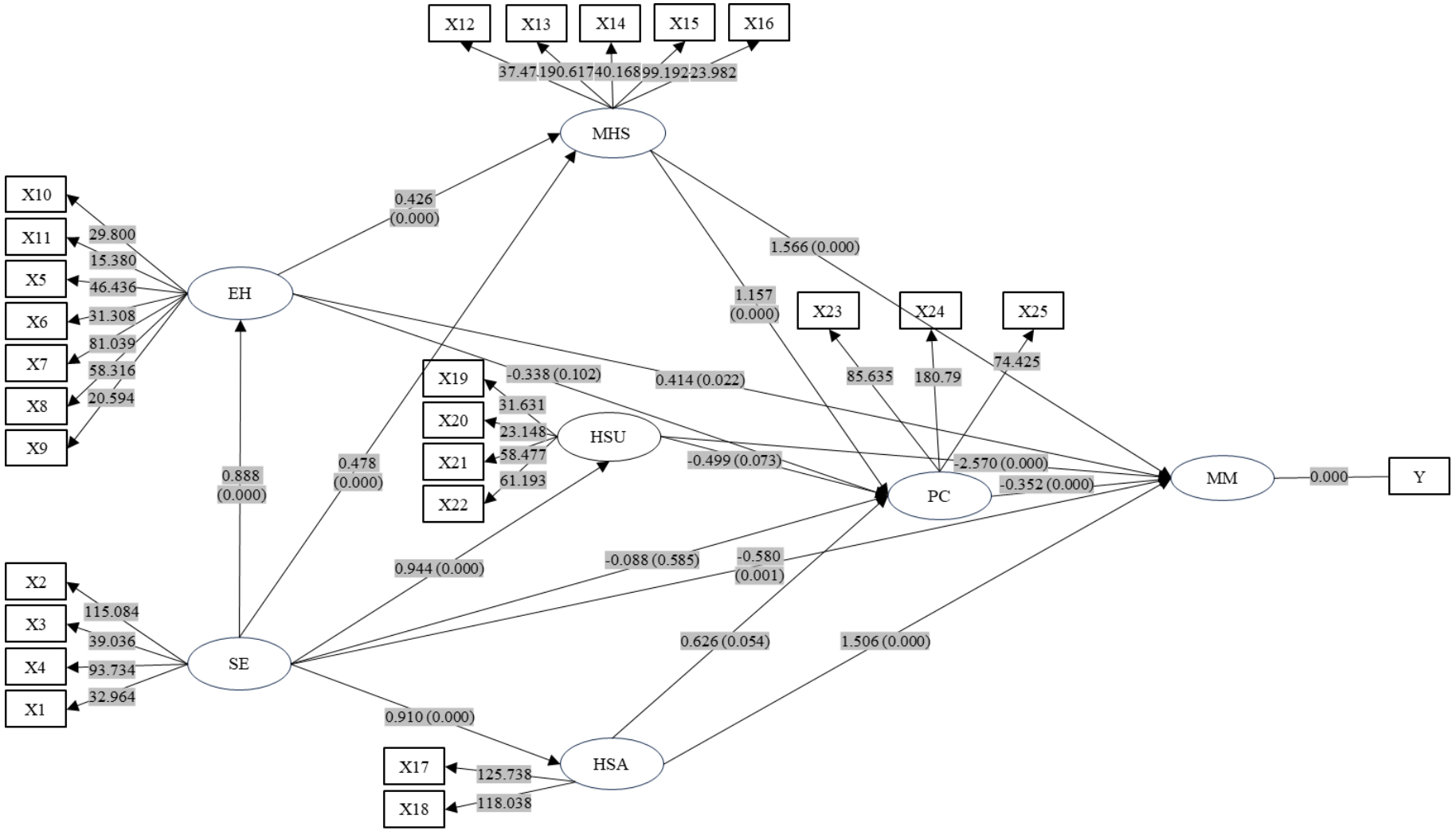

Figure 2. A diagram of the inner loading *p*-value SEM. EH: environmental health, SE: socioeconomic, MHS: maternal health status, HSU: health service utilization, HSA: health service access, PC: pregnancy complications, MM: maternal mortality. Standardized path coefficients are reported with the following significance levels: path coefficients (significant level), $p < 0.05$, positive and negative values in path coefficients reflect the direction of effect of exogenous factors on endogenous variables.

Table 3. Significance level based on the SEM diagram (in Figure 2) and model equation values

No.	Maternal mortality pathway	Significance status	Model equation values (%)
1	Socioeconomic > maternal health status > pregnancy complications > maternal mortality	Significant	13.94
2	Socioeconomic > maternal health status > maternal mortality	Significant	94.23
3	Socioeconomic > health service utilization > pregnancy complications > maternal mortality	Not significant	-
4	Socioeconomic > health service utilization > maternal mortality	Significant	1.71
5	Socioeconomic > pregnancy complications > maternal mortality	Not significant	-
6	Socioeconomic > environmental health > maternal health status > pregnancy complications > maternal mortality	Significant	87.72
7	Socioeconomic > environmental health > maternal health status > maternal mortality	Significant	97.00
8	Socioeconomic > environmental health > pregnancy complications > maternal mortality	Not significant	-
9	Socioeconomic > environmental health > maternal mortality	Significant	84.16
10	Socioeconomic > health service access > pregnancy complications > maternal mortality	Not significant	-
11	Socioeconomic > health service access > maternal mortality	Significant	97.79

The arrow (>) indicates the direction of effect on maternal mortality.

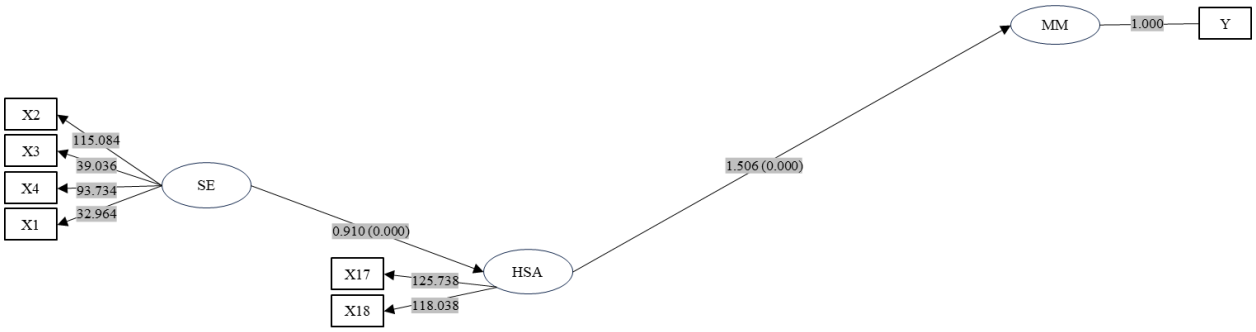

Figure 3. The most effective approach for reducing maternal mortality. SE: socioeconomic, HSA: health service access, MM: maternal mortality

Socioeconomic factors significantly influence the occurrence of maternal mortality by impacting mothers' health status, pregnancy complications, healthcare service utilization, environmental health, and access to healthcare facilities. The computation of the model equation highlights a key finding: the socioeconomic model notably influences the accessibility of health services, thereby affecting maternal mortality (see Table 3). This finding is supported by a statistically significant p-value, particularly $p = 0.000$. The exogenous elements exert a favorable impact on the endogenous variables, as evidenced by the positive path coefficients depicted in Figure 3. Improved socioeconomic conditions within a family contribute to greater availability of health care, leading to a reduction in maternal mortality rates (Y). The value of the model equation (Table 3) provides a simulated demonstration of how the intervention employing the major socioeconomic factors can reduce the incidence of maternal mortality. The intervention implemented via the model equation 11 pathway had the greatest efficacy in reducing the incidence of maternal mortality, with a reduction rate of up to 97.79% (Table 3). Furthermore, this reliable indicator measures socioeconomic position. This study incorporates these findings as relevant data for formulating regional policies aimed at reducing maternal mortality.

4. Discussion

This study introduces a prediction model for maternal mortality that considers three crucial factors: distant determinants (socioeconomic, environmental health), intermediate determinants (maternal health status, access to health services, utilization of health services), and immediate determinants (pregnancy complications). The research provides evidence of the direct and indirect influence of each variable on the incidence of maternal mortality. SEM is particularly suitable for assessing

intricate systems by detecting and quantifying the mediating effects that are frequently disregarded in empirical studies [38].

The bivariate analysis indicates that socioeconomic factors, maternal health status, health services utilization, and pregnancy complications significantly influence maternal mortality. Maternal mortality rates were notably high, reaching 78.9%, particularly among families classified in the lower middle-class bracket with an income below 500,000 rupiah. Socioeconomic status plays a pivotal role in maternal mortality rates by affecting several interconnected factors. Socioeconomic coverage involves assessing two primary factors: household income level and social class. The relationship between socioeconomic factors and the occurrence of maternal mortality is established by the findings of SEM study. The socioeconomic hypothesis test shows that access to health services reduces maternal mortality (p=0.000). The level of family income is a significant determinant in the provision of care for pregnant women. Mothers from low-income families will have challenges in reaching their daily nutritional requirements. Low-income households typically exhibit limited educational attainment, resulting in a lack of comprehension regarding the health and nutritional requirements of expectant mothers [39]. According to Suryaningsih [40], education emerges as a key determinant in maternal mortality rates. Further evidence underscores the detrimental impact of insufficient education on the persistently high maternal mortality rates [41]. Additionally, the distant availability of health service facilities contributes to notable delays in treatment for expectant mothers. The availability of private transportation also influences maternal mortality rates. Consequently, pregnant women experience delays in reaching hospitals during emergencies, resulting in delayed assistance and medical care. Travel duration significantly affects the accessibility of services for pregnant women [42].

The presence of transportation directly affects the accessibility of health treatment facilities. For timely and adequate healthcare provision, public health facilities must be easily reachable [43,44]. The combination of poor socioeconomic status, considerable distances to health services, and limited private transportation exacerbates maternal mortality. According to Arisukwu [45], inadequate access to healthcare services is the primary cause of the high maternal mortality rate, with nearly 99% of maternal fatalities attributed to this cause [46]. Mothers residing in isolated regions face higher probabilities of encountering difficulties due to inadequate service accessibility, as healthcare facilities are often located far from their homes [47]. Moreover, the prevalence of pregnancy complications increases when individuals have limited access to health services. Hanson's Tanzanian research [32] highlights a direct correlation between maternal mortality and hospital distance: the risk of maternal mortality decreases when the distance from home to health facilities is less than 5 km, but increases with distances equal to or greater than 35 km. Expectant mothers who live far from medical facilities often opt for traditional birth attendants or midwives over obstetricians [48,49]. Accessibility hinges on the geographical proximity of healthcare facilities to women seeking treatment, considering factors such as sufficient funding and range of treatments offered [50].

This study has generated four revised theories through analysis and statistical studies. These theories are as follows: (1) Socioeconomic factors are identified as the primary cause of maternal mortality, forming the basis for the development of public policies aimed at reducing such mortality rates; (2) Environmental health, initially viewed as a distant determinant, is now reclassified as an intermediate variable. This reclassification is supported by modeling outcomes, indicating that (3) environmental health factors influence both maternal health status and pregnancy complications, directly impacting maternal mortality. Addressing these factors through public policy interventions can help mitigate maternal mortality rates. Additionally, (4) each variable within the intermediate determinants category directly contributes to the incidence of maternal mortality. The final modeling output provides pertinent information for decision-makers to consider. Alongside the novel theory derived from data analysis, the modeling results serve as valuable assessment material for formulating future policies aimed at reducing the high rate of maternal mortality [51].

5. Conclusions

This novel SEM analysis uses representative data to analyze the complicated linkages between distant, intermediate, and immediate maternal mortality variables. These results confirm that socioeconomics is the sole distant factor affecting maternal mortality. The implication model, with 97.79% dependence on socioeconomics (distant determinant) and health services (intermediate determinant), offers the most accurate prediction of maternal mortality. Furthermore, this study emphasizes the need to improve policies and programs to reduce maternal mortality by providing health services in each community settlement, employment opportunities to increase economic income, improved maternity facility usability, and promotive, curative, and preventive interventions.

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