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# Multiple Exponential Regression Modeling of Dengue Haemorrhagic Fever Factors in West Java Province, Indonesia

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**Abstract**

Dengue Haemorrhagic Fever is a major public health problem in Indonesia, with 103,509 cases of Dengue Haemorrhagic Fever recorded in Indonesia until the end year of 2020 with 725 deaths with the case fatality rate of 0.70%, and an incidence rate of 38.15 per 100,000 population. The aim of this research is to determine the multiple exponential regression model for the number of Dengue Haemorrhagic Fever cases and its factors in the West Java Province, Indonesia, at the time period of 2020. This research uses secondary data sourced from *Open Data Jabar* and *Badan Pusat Statistik* in the form of the number of the Dengue Haemorrhagic Fever cases in each regency or city throughout the West Java, with the independent variables; the number of poverty rate, the number of healthcare workforces, population density, and number of households with adequate sanitation. The final model from the multiple exponential regression shows that population density has a significant effect on the number of Dengue Haemorrhagic Fever cases in the West Java Province.

**Keywords:** Dengue Haemorrhagic Fever; Exponential; Multiple Regression

## I. Introduction

Dengue Haemorrhagic Fever (DHF) is one of the major public health problems in Indonesia. The tropical climate of Indonesia supports the proliferation of various vector-borne diseases; hence it is one of the largest tropical countries in Southeast Asia with the highest number of DHF cases. This disease can occur throughout the year and attacks all age groups, both men and women.

Based on data released by the Ministry of Health, by 2020, cases of DHF recorded in Indonesia were 103,509 cases with 725 deaths, at the case fatality rate (CFR) of 0.70%, and an incidence rate of 38.15 per 100,000 inhabitants. In the last 3 years, the number of cases and infected areas have continued to increase and spread widely. By the year 2017, the number of DHF cases recorded in Indonesia was 68,407 cases with 493 deaths, a CFR of 0.72%, and an incidence rate of 26.10 per 100,000 population. Meanwhile, in 2018 the number of DHF cases recorded in Indonesia was 65,602 with 467 deaths, a CFR of 0.71%, and an incidence rate of 24.73 per 100,000 population. And in 2019, the number of DHF cases in Indonesia was recorded at 138,127 cases, with 919 deaths, the CFR was 0.67% and the incidence rate was 51.58 per 100,000 population. The distribution of the DHF cases in Indonesia can be seen in the Figure 1 and Figure 2 below.

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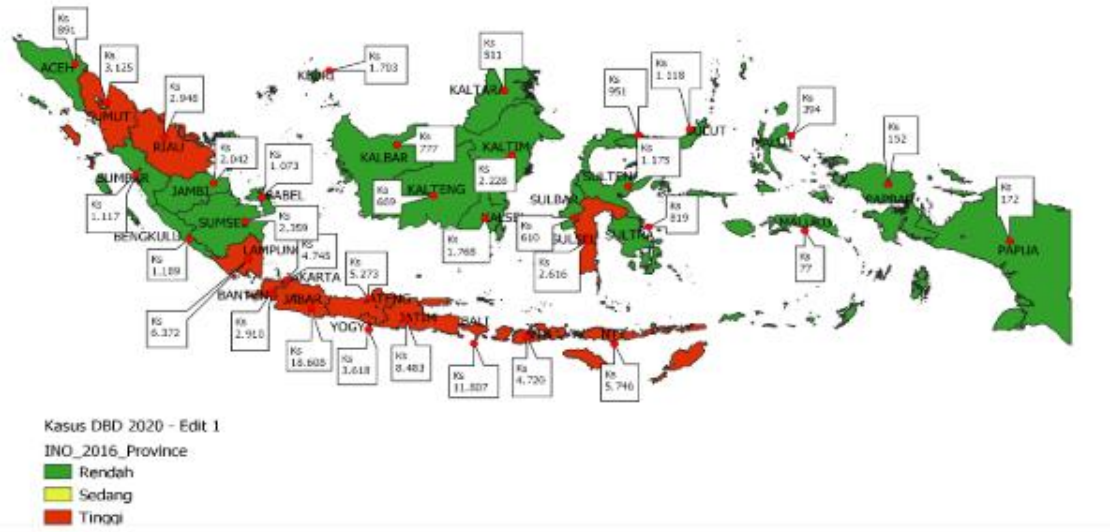


Figure 1. Visualization of DHF Cases in Indonesia

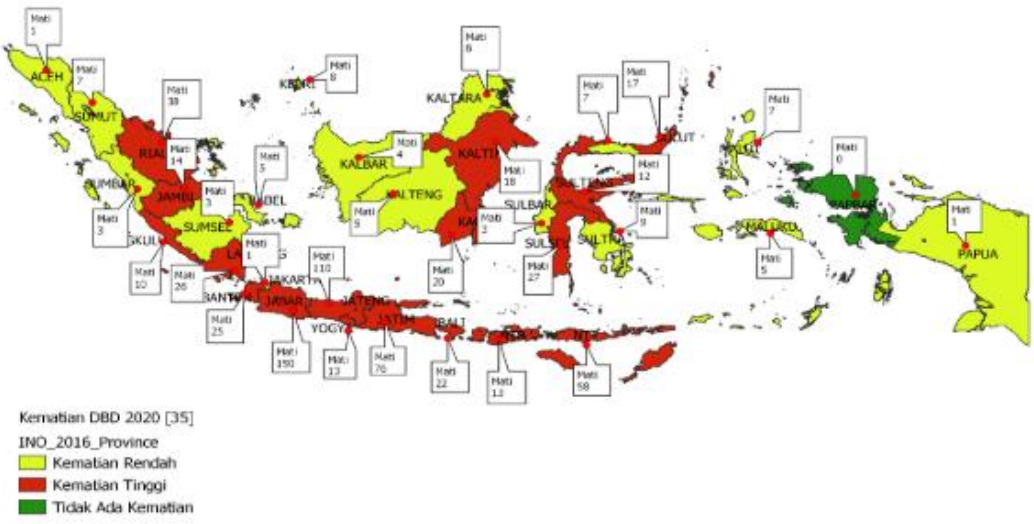


Figure 2. Visualization of Deaths Due to DHF in Indonesia

The mobility between regions, climate change, and unhygienic living habits are the few factors that may increase the spread of this virus. Economic problems could be a factor in an increase in the ability to move between regions. A previously non-endemic area could become an endemic area. An unhygienic home environment could also increase the population of *Aedes* mosquitoes in the home's neighborhood, thus increasing the risk of spreading dengue cases.

According to previous research, factors that influence the occurrence of DHF can be seen in several ways, one of which is the home environment. Residential environments that are too dense could easily become an easier place for the *Aedes* mosquitoes to spread the fever. So, the number of DHF cases align with how dense the neighboring areas are.

The environment in a persons' home itself is also a factor of Dengue Haemorrhagic Fever's occurrence. This can be seen in the placement of house furniture; the material, shape, colors, as well as the depth of the water, the cover and the origin of the water which greatly influence the reproduction of the *Aedes* mosquitos.

Another cause of DHF outbreaks in the environmental aspect is due to the environmental state of hygiene. This can be seen from the piles of trash, clothes, and a dirty water reservoir. There are a few cases of DHF who are proven to have unhygienic sanitation, such as no ceilings, trash bins that do not meet the requirements, and waste channels that are dumped directly into rivers without going through a processing process. According to Septiani and Sitorus [1], environmental factors such as population density which is not balanced with adequate housing and poverty are factors that also increase the number of DHF cases. These factors can be combined and represented with the Human Development Index.

In the Human Development Index, poverty is one of the fundamental problems that is the center of attention throughout the world, including Indonesia. Poverty here refers to a state of loss or deficiency in fulfilling basic needs, such as food, education, health, and others. Hence why an appropriate analysis is needed to figure out more factors influencing the increasing number of DHF cases in the West Java Province so a more accurate strategy would be able to decrease the number of DHF cases in the West Java Province.

Regression analysis is a statistical technique used to model the relationship between dependent variables and independent variables. In regression analysis there is linear and also non-linear regression, where in non-linear regression there is exponential regression. Exponential Regression itself is divided into 2 categories, namely the simple exponential regression model and the multiple exponential regression model. Multiple Exponential is a development of the exponential regression model where in the double exponential regression model there are two or more independent variables to one dependent variable [2].

This research will contribute in the heath fields to complement the other previous research about DHF and know specifically what and which are the influencing factors of DHF cases in West Java, Indonesia using the exponential regression model method. By analyzing the factors influencing the incidence of this disease, this research aims to help improve understanding of how environmental, mobility, and socio-economic conditions contribute to DHF spread.

By reading this research it is hoped that readers can use this as an evaluation for the stakeholders in the future so that it can reduce the risk and impact of the large number of DHF cases in the West Java Province, Indonesia. This journal will combine mathematics, statistics, and public health, providing a unique perspective on how quantitative methods can be applied to real-world health problems. So, people that work in the health and government sectors are strongly advised to read this research so they can plan dengue prevention and treatment strategies in West Java, as well as to increase public awareness about the risks and symptoms of dengue fever.

## II. Methods

### *A.* Exponential Regression

Non-linear regression is a method for obtaining a non-linear model that states the dependent variable and independent variables. If the functional relationship between the independent variable (X) and the dependent variable is non-linear, transform the non-linear form into linear form. To obtain linearity from non-linear relationships, transformations can be carried out on the dependent variable or independent variable or both [3].

Exponential regression analysis is a non-linear regression whose dependent variable has an exponential distribution. One of the methods used to estimate parameters in the exponential regression model is the Ordinary Least Square method. Exponential regression analysis can be developed into multiple exponential non-linear regression analysis and the model used is by using two or more variables $X_1, X_2, \dots, X_k$ as independent variables and one variable Y as the dependent variable. The general form of the multiple exponential regression equation is as follows:

$$Y_i = e^{\beta_0+\beta_1 X_{1i}+\beta_2 X_{2i}+\cdots+\beta_k X_{ki}}\varepsilon_i; i = 1,2,\dots,n \quad (1)$$

with $Y_i$ as the i-th observation value, $X_{1i}, X_{2i}, \dots, X_{ki}$ as the value of the variable X with $i = 1,2, \dots, n$, and e value of 2,71828, $\beta_{1i}, \beta_{2i}, \dots, \beta_{ki}$ as parameters, also $\varepsilon_i$ as the i-th residual.

To test whether the data has an exponential distribution, the Kolmogorov-Smirnov test can be used. The Kolmogorov-Smirnov test is a non-parametric statistical test used to compare between two different distributions. In this case, to test whether the data has an exponential distribution, the data distribution will be compared with the exponential distribution. The Kolmogorv-Smirnov test will be conducted with the following formulation:

$$D = max|F_0(x) - S_N(x)| \tag{2}$$

$F(Y_i)$ is the cumulative probability distribution. Wherein if $D \geq Z_{N;\alpha}$ or *p-value* $\leq \alpha$, reject the null hypothesis; otherwise, accept the null hypothesis.

*B. Estimate The Exponential Regression Model's Parameters*

*1. Transformation of Multiple Exponential Models*

To obtain linearity from a non-linear relationship, a transformation from non-linear form to linear form on the dependent variable is needed [4]. We first linearize the double exponential model in the general form of the exponential regression model to find the linear model, namely by using the natural logarithm, so that the model becomes $lnY_i = \beta_0 + \beta_1 X_{1i} + \beta_2 X_{2i} + \beta_k X_{ki}$, and the model can be rewritten as:

$$Y_i = \beta_0 + \beta_1 X_{1i} + \beta_2 X_{2i} + \beta_k X_{ki} + \varepsilon_i \tag{3}$$
with: $Y_i = lnY_i$, dan $\varepsilon_i = ln\varepsilon_i$

To simplify the solution of the equation above, as the following illustration:

$$P_i = A_0 + A_1 X_{1i} + A_2 X_{2i} + \cdots + A_k X_{ki} + \varepsilon_i \tag{4}$$

From the equation above, the distinction is made from the following information below:

$$P_i = lnY_i, X_i = X_i, A_0 = \beta_0, A_1 = \beta_1, A_2 = \beta_2, A_k = \beta_k, \text{ and } \varepsilon_i = ln\varepsilon_i. \tag{5}$$

We then estimate the Multiple Exponential regression transformation model in the equation below:

$$\widehat{P_i} = \widehat{A_0} + \widehat{A_1} X_{1i} + \widehat{A_2} X_{2i} + \cdots + \widehat{A_k} X_{ki} \tag{6}$$

To determine the estimated coefficients of the model above which is denoted by $\widehat{A_0}, \widehat{A_1}, \widehat{A_2}, \dots, \widehat{A_k}$, use the OLS method based on estimating the parameters of the multiple linear regression equation, namely the multiple linear regression equation. We then test the exponential regression model's parameters, both simultaneously and individually to find out which variables we have that do and do not have an influence on the dependent variable.

*2. Simultaneous Testing of Parameter Significance (F-test)*

Simultaneous tests were carried out to test the influence of all predictor variables in explaining changes in the value of the response variable. The F-test will be conducted with the following test statistic:

$$F = \frac{\frac{R^2}{k-1}}{1 - \frac{R^2}{n-k}} \tag{7}$$

wherein if the $F_{value} > F_{table(\alpha;(k-1),(n-k)}$ or the *p-value* ≤ α, reject the null hypothesis; otherwise, accept the null hypothesis.

*3. Partial Testing of Parameter Significance (T-test)*

Partial tests are used to test how far the influence of individual predictor variables is in explaining the variance of the response variable. The T-test will be conducted with the following test statistic:

$$t_{value} = \frac{\widehat{B}_j}{SE(\widehat{B}_j)} \tag{8}$$

wherein if the $t_{value} > t_{table(\frac{\alpha}{2},(n-k))}$ or the *p-value* ≤ α, reject the null hypothesis; otherwise, accept the null hypothesis.

*4. Coefficient Determination $R^2$*

The coefficient determination is able to provide information regarding variations in the value of the dependent variable which can be explained by the regression model used [5].

$$R^2 = \frac{\sum_{i=1}^{n} \left(Y_i - \widehat{Y}_i\right)^2}{\sum_{i=1}^{n} \left(Y_i - \underline{Y}\right)^2} \tag{9}$$

where $Y_i$ = dependent variable value, $\underline{Y_i}$ = the average value of the dependent variable, and $\underline{Y_i}$ = predicted value.

*C. Multiple Exponential Regression Model's Diagnostic Test*

*1. Multicollinearity*

Multicollinearity is a situation where there is a correlation between the independent variables. Multicollinearity is the level of linear relationship between explanatory variables or regressors in a regression equation. When there is more than one explanatory variable, multicollinearity evaluation must be carried out because this is included in the data problem. Multicollinearity could be seen from the results of $det(X^TX) = 0$ and from the value of Variation Inflation Factors or VIF. There is no multicollinearity if the value of VIF has a number of 5 and/or 10 or more. With the VIF formula as follows:

$$VIF_j = \left(1 - R_j^2\right)^{-1} \tag{10}$$

*2. Homoscedasticity*

Homoscedasticity is a classic assumption test to determine whether the residual value variance in a regression model is constant or not. If the Homoscedasticity assumption is not met then it can be said that the model assumption is not good. The Breusch-Pagan test will be conducted with the following test statistic:

$$n(R^2) \tag{11}$$

where n = sample size; $R^2$ = Determination coefficient of the squared residual regression of the original regression. Wherein if $X^2 > X^2_{table(\alpha,k)}$ or $p\ value \leq \alpha$, reject the null hypothesis; otherwise, accept the null hypothesis.

*3. Autocorrelation*

Autocorrelation is a residual assumption that has components or values that are correlated based on time sequence in the data set itself. We test autocorrelation by the Durbin-Watson method [5]. First, we can perform regression with OLS and get residuals $e_i^2$. Then, calculate the DW (Durbin-Watson) test statistics as follows:

$$d = \frac{\sum_{i=2}^{n}(e_i - e_{i-1})^2}{\sum_{i=2}^{n} {e_i}^2} \tag{12}$$

where $e_i$ = residual value $(Y_i - \hat{Y}_i)$; and $e_{i-1}$ = previous residual value. The $H_0$ rejection criteria can be seen in Table 1.

Table 1. Reject the null hypothesis criteria

| DW's Value | Result |
|---|---|
| $0 < \text{DW} < d_L$ | Reject The Null Hypothesis |
| $d_L \leq \text{DW} \leq d_U$ | Critical Region |
| $d_U < \text{DW} < 4 - d_U$ | Accept The Null Hypothesis |
| $4 - d_U \leq \text{DW} \leq 4 - d_L$ | Critical Region |
| $4 - d_L \leq \text{DW} \leq 4$ | Reject The Null Hypothesis |

*4. Residual Normality*

The residual normal test can be used in various ways, one of which is the Shapiro-Wilks test. The following is the formula for the Shapiro-Wilks test:

$$T_3 = \frac{1}{D}\left[\sum_{i=1}^{n} a_i (x_{n-i+1} + 1 - x_i)^2\right] \tag{13}$$

where $n$ = sample size; $D = \sum_{i=1}^{n}(x_i - \underline{x})^2$; $a_i$ = Shapiro-Wilks test coefficient; $x_{n-i+1}$ = Data section $n - i + 1$; $x_i$ = $i_{th}$ data ; and $\underline{x}$ = mean of data. Wherein if the $p - value \leq \alpha$; reject the null hypothesis; otherwise, accept the null hypothesis.

## III. Result and Discussion

*A. Data Description*

This research uses secondary data obtained from the West Java Provincial Health Service in 2020 by the publications of *Open Data Jawa Barat dan Badan Pusat Statistik Jawa Barat*. We use the dependent variable of the number of DHF cases in each district or city in the West Java Province of Indonesia and the independent variables this research uses are poverty rate ($X_1$), healthcare workforces ($X_2$), population density ($X_3$), and the number of households with access to adequate sanitation ($X_4$).

Table 2. Each Variable's Description

| Variables | Min | Max | Mean | Std. Dev |
|---|---|---|---|---|
| Y | 146 | 4424 | 906.3 | 893.7432 |
| $X_1$ | 11200 | 465700 | 145193 | 99672.73 |
| $X_2$ | 219 | 2342 | 1211.8 | 642.1671 |
| $X_3$ | 424 | 14916 | 3821.6 | 4515.694 |
| $X_4$ | 3092 | 388620 | 50320 | 78255.14 |

The data analyzed was a total of 27 observations, with the average number of DHF cases being 906.3 people, with the lowest number of cases being 146 people and the highest being 4,424 people. With the value of the average poverty rate ($X_1$) worth 145,193, with the lowest poverty rate namely 11,200 and the highest, 465,700, and has a standard deviation value of 99,672.73. Average healthcare workforces ($X_2$) is 1,211.8, with the lowest healthcare workforce being 219 people and the highest being 2,342 people, with a standard deviation value of 642.1671. The average of the population density ($X_3$) value is 3,821.6, with the lowest value being 424 people per square kilometer and the highest being 141916 people per square kilometer, with a standard deviation value of 4,515.694. On average, households with access to adequate sanitation ($X_4$) is worth 50,320, with the lowest value being 3,092 and the highest value being 388,620 houses, with a standard deviation of 78,255.14.

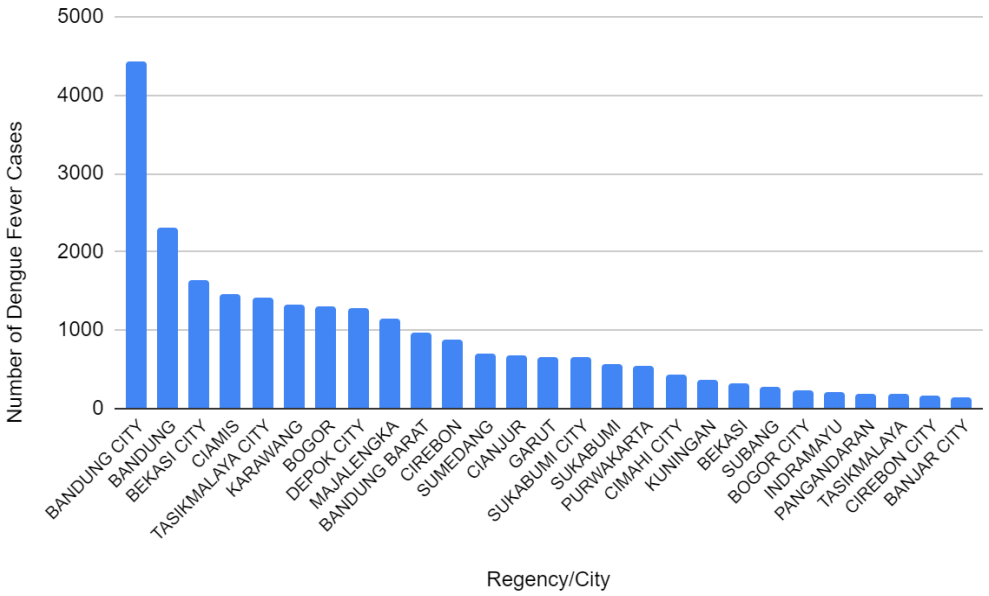


Figure 3. Visualization of The DHF Cases in Each Regency and/or City in The West Java Province of Indonesia in The Year 2020

The number of cases of DHF in each regency and/or city in the West Java Province of Indonesia by the year of 2020 is presented in Figure 3. The spread of this disease covers 18 regencies and 9 cities. The figure shows that the highest number of DHF cases was in Bandung City with 4,424 cases, while the lowest number of DHF cases was in Banjar City with 146 cases. The total number of DHF cases in West Java Province is 24,471 people.

*B. Kolmogorov-Smirnov Test*

After testing the exponential distribution on the dependent variable, the calculated value was 0.14878, and had a *p-value* of 0.5885. So it can be decided that we accept the null hypothesis, which means that the number of DHF cases in the West Java Province have an exponential distribution. Hence, we could use the exponential regression modeling to model the DHF cases with this study's variables.

*C. Multiple Exponential Regression Model*

The initial multiple exponential regression model is as follows:

$$Y_i = e^{\beta_0+\beta_1 X_{1i}+\beta_2 X_{2i}+\beta_3 X_{3i}+\beta_4 X_{4i}}\varepsilon_i, i = 1,2,\dots,27 \quad (14)$$

with $Y_i$= number of DHF cases for each i-th observation, $X_1$= poverty rate, $X_2$= healthcare workforces, $X_3$= population density, $X_4$= number of households with access to adequate, $\beta_0, \beta_1, \beta_2, \beta_3, \beta_4$ = the exponential regression model's parameters, and $\varepsilon_i$= the error of the model.
The formula of the estimated multiple exponential regression transformation model is in the equation below:

$$\widehat{P_i} = \widehat{A_0} + \widehat{A_1}X_{1i} + \widehat{A_2}X_{2i} + \widehat{A_3}X_{3i} + \widehat{A_4}X_{4i} \quad (15)$$

So the estimation of the multiple exponential regression model after transforming the dependent variable can be seen in the equation below:

$$\widehat{P_i} = 0.5295 + 0.00000614X_1 + 0.00005214X_2 + 0.00009279X_3 - 0.000003348\,X_4 \quad (16)$$

The plot of the multiple exponential regression model's residuals can be seen in Figure 4.

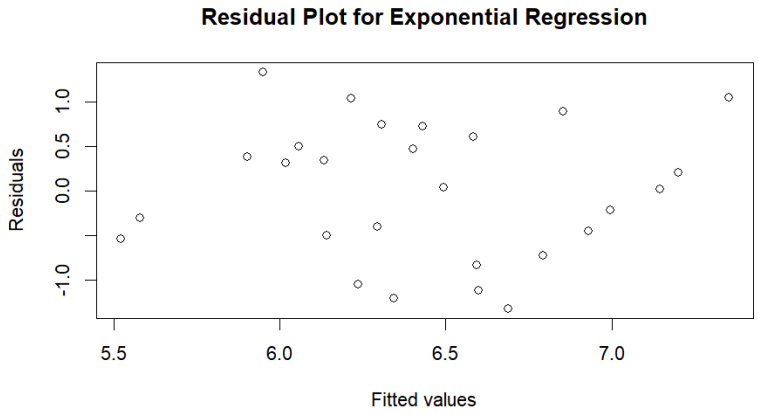


Figure 4. Visualization of the Multiple Exponential Regression Models' Residuals

*D. Parameter Significance*

Before we conclude and implement the exponential regression model, the parameters need to be tested both simultaneously and partially.

*1. Simultaneous Test (F-Test)*

The *p-value* we obtained was at 0.1164, with the number of $F_{value}$ equals to 2.091. With a *p-value* (0.1164) > α (0.05), the same as $F_{value}(2.091) < F_{(0.05;4,2)}$ (2.816). Therefore, simultaneously, the independent variables do not explain the dependent variable's variations in the model.

*2. Partial Test (T Test)*

Table 3. Partial Testing (t Test)

| Variables | t | *p-value* |
|---|---|---|
| Y | 10.9866129 | 0.00 |
| $X_1$ | 1.867639 | 0.08 |
| $X_2$ | 0.1405795 | 0.89 |
| $X_3$ | 2.3141011 | 0.03 |
| $X_4$ | -0.9785718 | 0.34 |

The results obtained from the partial test can be seen in Table 3 above. For the constant parameter, the *p-value* obtained is 0.00, therefore we reject the null hypothesis, which means there is a significant influence of the constant parameter on the number of dengue cases in the exponential regression model. We can see in Table 3 that the population density also rejects the null hypothesis, which means there is a significant influence of the population density variable on the variable number of DHF cases. These findings align with previous studies that explain the relationship between population density and DHF showed a positive relation, meaning the higher the population density, the higher the DHF cases are in [6].

A previous study showed similar findings, whereas population density has a big contribution in DHF cases. Dense and narrow households are easier for dengue transmission to occur, as the range of flying distance of the Aedes mosquitoes is around 50 meters [7]. It is known that a female Aedes mosquito only visits one or two houses and a visit of 0.7% into five houses [4]. Not only that the mobility in a narrow population heightens the potential of dengue virus transmission, the quality of housing, lighting, household shape, and building materials, may also affect the transmission of DHF [6].

Population growth that has no specific pattern and uncontrolled urbanization are the factors contributing to the population density, which affects the emergence of DHF [8]. However, some previous studies showed different findings regarding the relation between population density and DHF cases. DHF control in Kendari City, South East Sulawesi, Indonesia, did not have a correlation with population density in the time period of 2014 until 2018 [9]. Whereas in East Java, Indonesia, the denser the population, the fewer the number of DHF cases are, and vice versa [10]. These contradictory results may occur due to the heterogeneity in dengue control measures and the socioeconomic indicators of the analyzed areas [11], and may be a good explanation of the occurrence of dengue in urban and rural regions or cities within the West Java Province.

### *E. Diagnostic Test*

After carrying out the diagnostics test, we have the results for each test we needed to decide whether the exponential regression model is suitable for the dataset. We will break down the tests we have done for the model one by one.

Table 4. Multicollinearity Test Results

| Variables | VIF Values | Factors |
|---|---|---|
| $X_1$ | 4.138686 | Poverty Rate |
| $X_2$ | 2.185993 | Healthcare Workforces |
| $X_3$ | 1.263612 | Population Density |
| $X_4$ | 2.763346 | Households With Adequate Sanitation |

Firstly, it can be seen from Table 4 that there are no VIF values that exceed 5 or 10, so it can be concluded that in the exponential regression model, there are no problems with multicollinearity. Secondly, we also got a result that shows there is no heteroscedasticity problem in the model. Thirdly, the autocorrelation test was carried out and the results show the model has no autocorrelation problem. Finally, the normality test for the model's residuals is carried out and shows the residuals of the exponential regression model are normally distributed.

### *F. Coefficient Determination $R^2$*

The value of $R^2$ shows that 27.5% of the change of DHF cases can be explained by the poverty rate, the number of healthcare workforces, the population density, and the number of households with adequate access to sanitation, while the other 72.5% is explained by other data points that this research did not mention. DHF may be associated with poverty [12]. The many points of poverty such as; poor access to health services, adequate income, work, education, housing conditions, transportation, sustainable environment, and social support networks might lead to global health problems [13].

The number of workforces in the health field is also another keypoint that may be affecting the rising number of DHF cases. Providing the health field with dengue diagnostic tools and training would help the field in preventing the rise of DHF cases [14], as the knowledge of primary professional care regarding dengue determines the outcome of DHF control in the health field [15]. DHF has a close relation with sanitation. Sanitation is determined by the housing maintenance, the proliferation of Aedes mosquitoes, and poor natural housing environmental hygiene could also cause DHF by the spread of dengue virus [16]. A study found that poor physical housing conditions were indeed heavily correlated with DHF cases other than the rest of the poverty's important point [11].

The crowding of households and household density may also determine the number of DHF cases [17]. A very narrow range of the human population might increase the dengue virus transmission, with a high ratio between a mosquito, a human, and the lack of water supply in each of the households [18].

*G. Final Model of Multiple Exponential Regression*

The final results of the exponential regression model are obtained:

$$\begin{aligned} e^{P_i} &= e^{A_0 + A_3 X_3} \\ e^{lnY_i} &= e^{\beta_0 + \beta_3 X_{3i}} \\ e^{lnY_i} &= e^{5.295e01} e^{9.279e05 X_3} \\ Y_i &= 199.3369\, e^{0.00009279 X_3} \end{aligned} \tag{17}$$

From Equation (17), it can be seen that the coefficient value for each variable is very small. This indicates that the changes in DHF cases for each regency or city in the West Java Province of Indonesia for each data point will be very small. We also need to remember that from the partial test results above, only the population density has a significant effect on the number of DHF cases in each regency or city in the West Java Province. The absence of a significant correlation we can see in Table 3 may be due to the relatively small secondary dataset, consisting of only four data points. The dataset's quantity could also affect the significance value between the variables within the final exponential regression model [19].

## IV. Conclusion

Based on this study's findings and results, we can conclude that the final model of Multiple Exponential Regression used to explain the number of DHF cases and its data points is as follows:

$$Y_i = 199.3369\, e^{0.00009279 X_3} \tag{17}$$

From Equation (17), every one person per kilometer increase in population density, the number of DHF cases will increase by 1 time. From the research results, it can be seen that Population Density is a factor that has the most significant influence on the number of DHF cases in the West Java Province, Indonesia, at the time period of 2020.

This study has limitations. Firstly, the dataset used in this study is limited to the regions within West Java Province and only in the time period of 2020, which may not reflect on long-term trends. Generalizing the results of this study outside of West Java Province may not be accurate due to a different ecological and socio-economic condition with other provinces.

Secondly, the final model used in this study does not count external factors, such as climate change and population mobility. This could affect the lack of variability in the model. The exponential regression model used in this study is based on certain assumptions, but the assumed relationships of the dataset may not fully capture the complexity of real-world conditions, potentially affecting the validity of the predictions generated.

There are several potential issues that need to be addressed to enhance the understanding of the causes of dengue fever for future research. It is recommended to expand the data coverage by including a wider geographical range and a longer time period, which would provide a more comprehensive picture for

generalizing the results. It would also be important to incorporate external factors such as climate change and population mobility into the model to improve prediction accuracy. Last of all, future studies should explore the use of more complex models to capture the dynamics and variability of the data more effectively, thereby improving the validity and accuracy of the research findings.

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