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The effects of hydrometeorological disaster and potential conflicts on the human development index using linear mixed multilevel models

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ABSTRACT

As is generally known, the human development index (HDI) is formed from three main factors, namely education, health, and income, which measure the population's access to a decent standard of living. Using the linear mixed multilevel models, this study indicates that other factors beyond these three basic dimensions of HDI, namely hydrometeorological disasters and potential conflicts, significantly affect the HDI value. This research focuses on longitudinal data analysis from 27 regencies and cities in West Java, Indonesia, in the last four years until 2022, with the level of hydrometeorological disasters consistently increasing every year and an increasing trend in the number of potential conflicts. The dimensions of human life and other factors can affect the human development index, namely the number of hydrometeorological disasters and potential conflicts, which have a negative correlation so that the value of the HDI can be reduced if the intensity of hydrometeorological disasters increases and possible conflicts can be controlled. Moreover, this study shows that uncontrolled potential conflicts in each regency or city from time to time can reduce HDI values. Therefore, this research can be a reference for the government, stakeholders, and the community in carrying out work programs that are right on target to increase HDI consistently every year.

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INTRODUCTION

Indonesia is known as a region prone to natural disasters. The National Disaster Management Agency (BNPB) recorded that from 2010 to 2020, the Indonesian Disaster Data and Information Management Database (BNPB) recorded 24,969 incidents with 5,060,778 fatalities and 4,400,809 houses affected as well as public facilities. Damaged as many as 19,169 facilities spread throughout Indonesia (Badan Nasional

Penanggulangan Bencana, 2020). Apart from that, among the characteristics of Indonesia's disasters from 1815 to 2019, the highest number of disaster events were floods, followed by tornadoes, landslides, and fires (European Commission Staff, 2010).

A disaster can impact the soul, economy, and socio-politics, indirectly affecting the value of the human development index. The Human Development Index (HDI) is a level of human development value used to achieve results from the development of a region or region in the three basic dimensions of development (measuring per-capita income, education attainment, and life expectancy) (Ivanov, 2013). The United Nations Development Program (UNDP) states that HDI is a summary and not a comprehensive measure of the human development of a region (UNDP, 2022). The concept of human development must be centered on the population (Yasin, Hakim, & Warsito, 2020). Human development pays attention not only to efforts to improve human capabilities. Human development is supported by four main pillars: productivity, equity, sustainability, and empowerment (Suryani & Sartika, 2021).

The HDI of every regency or city in West Java Province almost always increases every year. That is equal to 0.31% on average per year. The HDI's growth results from an increase in the basic dimensions of development. Some HDIs grow fast, and some slow down. This condition is caused by the growth of the HDI components that are not evenly distributed or by other variables that affect the districts and cities in West Java Province. In addition to the often occurring hydrometeorological disasters, West Java Province is also not immune from community conflicts that can harm and hinder community activities, productivity, and growth, which will undoubtedly impact local human development. Many factors can affect the value of HDI, so it needs to be studied more deeply to increase or decrease the aspects that can increase the value of HDI.

Previous research discussed the effects of poverty and health on the human development index in Central Java Province, where the variables of poverty and health are closely related to the assessment of the human development index (Suryani & Sartika, 2021). Wang et al. (2018) investigated the association between renewable energy usage, economic growth, and the human development index in Pakistan. The formulation of the problem in this study based on the background above is the influence of hydrometeorological disasters and potential conflicts on the human development index in West Java Province, where the two variables are not directly related to the assessment of the human development index. This study examines the effect of hydrometeorological disaster events and possible matches on HDI in West Java Province in 2019–2022. This paper is structured as follows: We review several issues or areas that may affect the value of HDI. Then, we present our methodology, including datasets, cleansing data, and model building. We offer the results of the human development index model with mathematical equations and their significant values.

METHOD

Dataset and Data Exploration

This study used secondary data on HDI as the dependent variable and six independent variables: the average length of schooling, life expectancy, per capita income, expected length of education, the potential for conflict, and hydrometeorological disasters. This is a longitudinal study (Jiménez, Villegas, Salazar-Uribe, & Álvarez, 2020) in West Java for four years, from 2019 to 2022. Data were obtained from the Central

Bureau of Statistics, the Regional Disaster Management Agency, and the West Java Provincial Political Unity Agency through the Open Data Jabar official website.

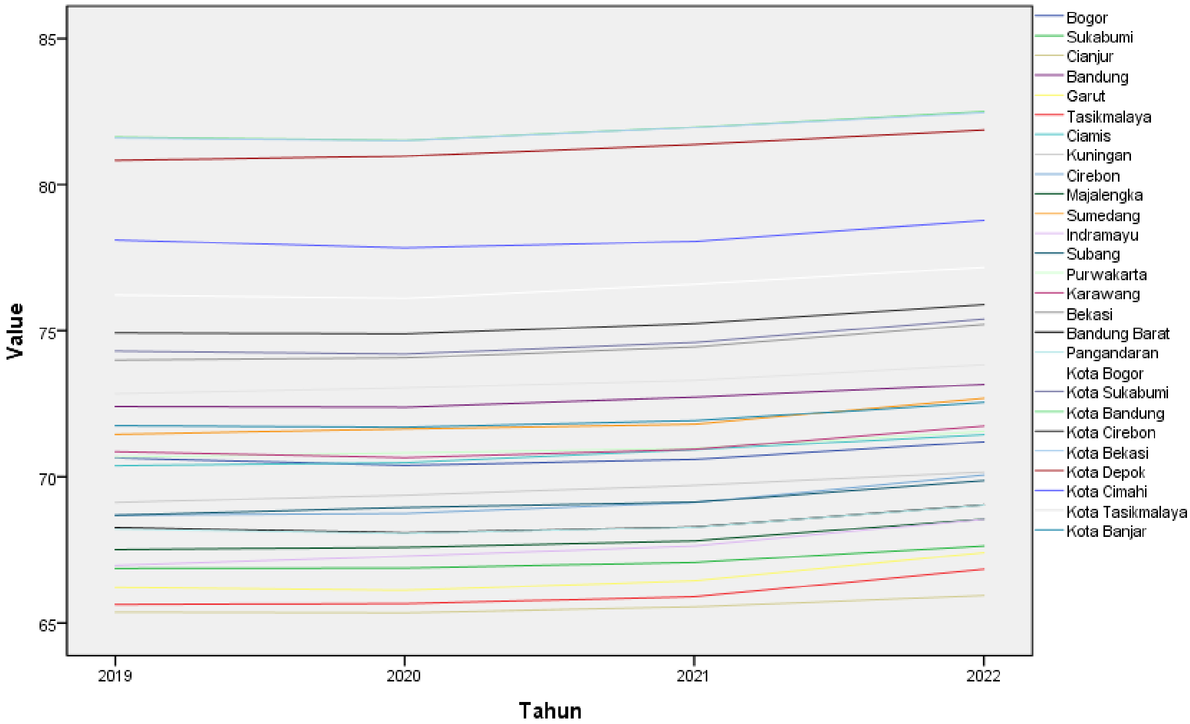

Figure 1. HDI Score in West Java

The human development index is a value used to measure the average achievement of a country in three fundamental aspects of human development: longevity, education, and standard of living (Herman, 2021). Index values range from 1-100, where the human development index measures the overall achievement of a region or country in the three basic dimensions of human development, namely longevity, knowledge, and a decent standard of living (Tarigan, 2021). It can be seen in Figure 1 that the human development index in West Java has almost the same trend every year and has a movement that tends to be linear over time. Still, although not much, it increases, with the highest HDI value not exceeding 83.

The potential for conflict has a random trend, as seen in Figure 2, with the provincial capital city of West Java, Bandung, having the most potential for conflict. Hydrometeorological disasters are disasters related to wind and water flow between the atmosphere and the earth. This data shows that hydrometeorological disasters include floods, tornadoes, landslides, earthquakes, natural fires, etc. Bogor regency and city areas have relatively higher rainfall intensity than other regencies and cities in West Java, so they also have higher hydrometeorological disaster data. Figure 3 Hydrometeorological disasters have a positive linear trend that increases yearly.

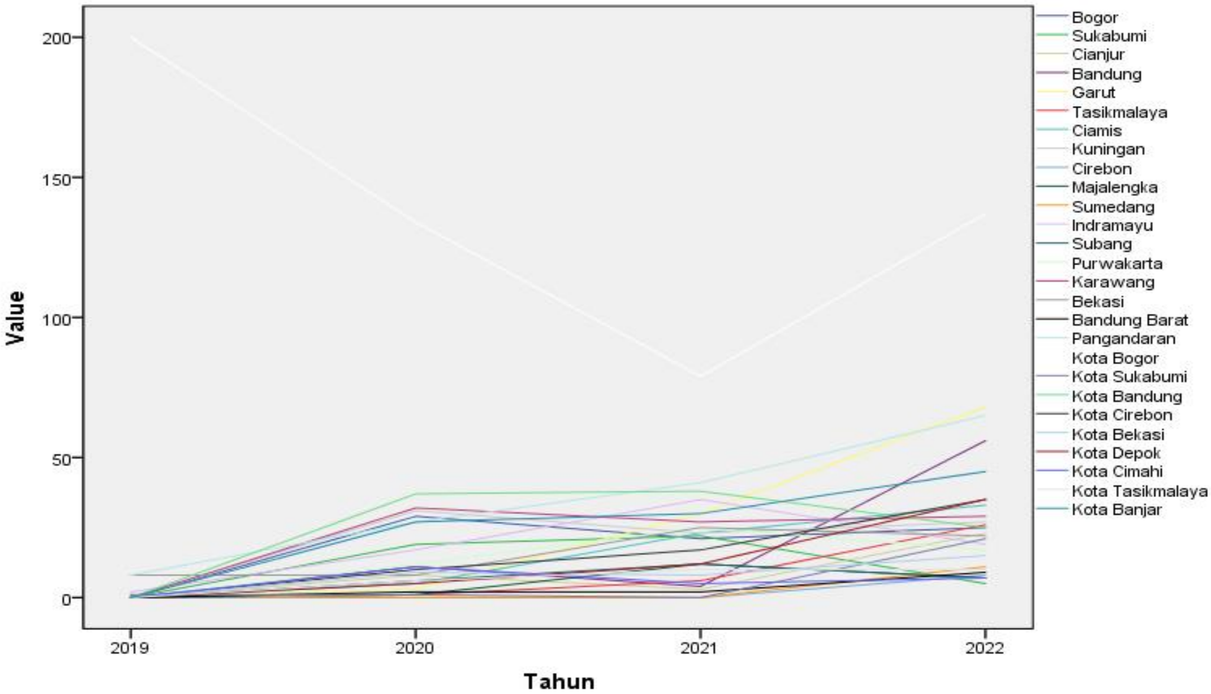

Figure 2. Potential Conflict in West Java

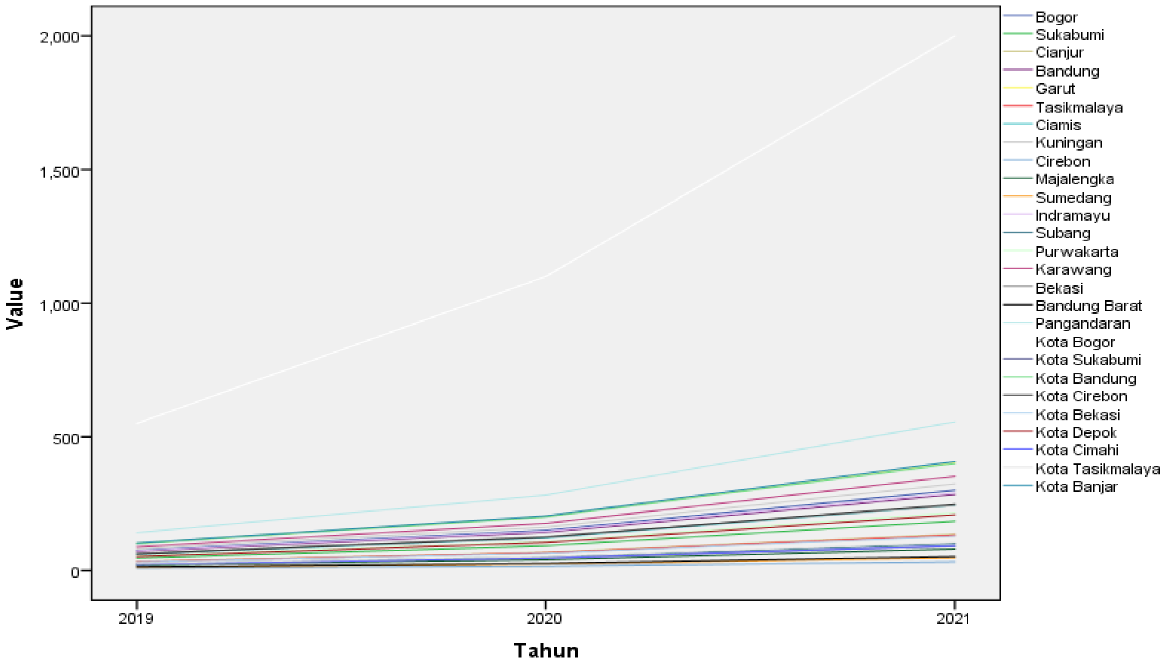

Figure 3. Hydrometeorological Disaster in West Java

The average length of schooling is the total number of years residents in West Java use to undergo formal education. It can be used to determine the quality of community education in an area. The average length of schooling in West Java has an increasing trend every year, and Depok City is the city in West Java with an enormous average length of schooling. Per-capita income is the total income in West Java and is then divided by the total population in West Java. Per-capita income has a trend that is almost the same every year, with the highest income in Bandung. The expected length of education is defined as the length of school expected to be experienced by children at a certain age. It has the same trend every year, and the highest score is in the provincial capital city of West Java, Bandung.

Linear Mixed Model

Linear and linear-mixed models are powerful and flexible models for understanding the world (Winter, 2013). Linear mixed models are more accurate and realistic than linear regression models (Gao, Zhan, Wang, Wang, & Zhu, 2019). The linear mixed model is the development of a linear model in which fixed and random effects affect the response variable (Zannah, Rizki, & Aprizkiyandari, 2022). The fixed effects are the explanatory variables, while the random effects are other additional effects that can make the model more natural, like conditions in the real world. Linear mixed models can be expressed in different but equivalent forms (Monsalves, Bangdiwala, Thabane, & Bangdiwala, 2020). In this study, two models were used, namely without random effects and with random effects, including variable clustering. For a model without random effects, the general form is:

$$Y_{ik} = \beta_0 + \beta_t t_k + \varepsilon_{ik},$$

with Y_{ijk} denoting HDI response variable from time k, regency or city i, and t_j denoting the time of observations, $t_k = 2019, 2020, 2021, 2022$, therefore β_0 denotes the intercept and β_t is the effect of time. As for models with random effects, the general form is:

$$Y_{ijk} = \beta_0 + \beta_t t_k + \beta_1 X_1 + \cdots + \beta_n X_n + \alpha_i + \gamma_j + \varepsilon_{ik}$$

with $\beta_1, \ldots, \beta_n$ are fixed effects $X_1, \ldots, X_n, \alpha_i$, and γ_j each expressing random effects of each regency or city clusters. Data processing and analysis were carried out with the help of the "*nlme*" package, specifically for mixed linear modeling.

RESULTS AND DISCUSSION

In the first step, we explored each independent variable that significantly affected the value of HDI in West Java Province without involving random effects. This means that we assume that each regency and city have the same average internal conditions for human development. We present Model 1, which is the simplest linear assumption without including random effects defined as

$$Y_{ik} = \beta_0 + \beta_t t_k + \varepsilon_{ik}$$
$$\varepsilon_{ik} \sim (0, \sigma^2_{res})$$

Table 1. Model 1 Test Results

	Value	Std. Error	p-value
Intercept	71.4745	0.7573	0.0000***
TIME	0.3225	0.4048	0.4273

Table 1 illustrates no significant effect of changes in time (year) on the value of HDI. This is evidenced by the TIME p-value of 0.4273. This can be related to the graph in Figure 1, which explains that the value of HDI each year has an upward trend but is very small. Because the results in Model 1 were insignificant, we continued the investigation by adding random effects to each regency or city area.

We then obtained a model that contained variables that had a considerable impact on Model 2. In this model, we assume α_i is the random regency/city effect.

$$Y_{ijk} = \beta_0 + \beta_1 t_k + \alpha_i + \varepsilon_{ik}$$
$$\alpha_i \sim N(0, \sigma^2_{ID}), \varepsilon_{ik} \sim (0, \sigma^2_{res})$$

Table 2. Model 2 Test Results

	Value	Std. Error	p-value
Intercept	71.4746	0.9134	0.0000***
TIME	0.3225	0.0198	0.0000***

Table 2 shows the significance and a solid direct proportional positive relationship of TIME 0.3225 with a very small p-value. Each district or city correlates with an increasing HDI every year. Then, to find a more significant model, we tried to develop model 3, namely by providing two clusters, districts and cities, noticed as random effects $b(i)$, to see the effect of differences in regional status on HDI defined as

$$Y_{ijk} = \beta_0 + \beta_1 t_k + b_{j(i)} + \varepsilon_{ijk}$$
$$b_{j(i)} \sim N(0, \sigma_{KK}^2), \varepsilon_{ijk} \sim (0, \sigma_{res}^2)$$

Table 3. Model 3 Test Results

	Value	Std. Error	p-value
Intercept	72.7791	0.9134	0.0000***
TIME	0.3225	0.2461	0.1927

It was found that regency and city clustering had no significant effect at any time on HDI. After adding random products and clustering, we tried to combine the two into Model 4 below.

$$Y_{ijk} = \beta_0 + \beta_1 t_k + \alpha_i + b_{j(i)} + \varepsilon_{ijk}$$
$$\alpha_i \sim N(0, \sigma_{ID}^2), b_{j(i)} \sim N(0, \sigma_{KK}^2), \varepsilon_{ijk} \sim (0, \sigma_{res}^2)$$

Table 4. Model 4 Test Results

	Value	Std. Error	p-value
Intercept	72.7561	3.9351	0.0000***
TIME	0.3225	0.0198	0.0000***

Table 4 shows significant results with a value of 0.3225 and a very small p-value; this means that each region in the regency and city strongly influences the value of HDI. It can be interpreted that with every year added, the value of HDI increases by 0.3225.

Table 5. Summary Model 1-4

Parameter Fixed Effect	Model 1	Model 2	Model 3	Model 4
Q_0	71.4746	71.4745	72.7791	72.7561
Q_1	0.3225	0.3225	0.3225	0.3225
Variance Component				
σ_{ID}^2	-	22.4934	30.8003	30.2588
σ_{KK}^2	-	-	8.1748	8.5278
σ_{res}^2	22.1221	0.0531	-	0.0531
Total	22.1221	22.5465	38.9751	38.8397

Table 5 shows that a good model is indicated by models 3 and 4 because they have a relatively small standard error and a significant variance. Next, we will conduct further research by analyzing the variance components and the correlation structure of the above models to determine the model used to develop the HDI model. Various models use different decompositions with total variability.

$$Model\ 1: \hat{\sigma}^2 = \hat{\sigma}_{res}^2 = 22.1221$$
$$Model\ 2: \hat{\sigma}^2 = \hat{\sigma}_{ID}^2 + \hat{\sigma}_{res}^2 = 22.49344 + 0.053099 = 22.5456$$
$$Model\ 3: \hat{\sigma}^2 = \hat{\sigma}_{ID}^2 + \hat{\sigma}_{KK}^2 = 30.8003 + 8.1748 = 38.9751$$
$$Model\ 4 = \hat{\sigma}_{ID}^2 + \hat{\sigma}_{KK}^2 + \hat{\sigma}_{res}^2 = 30.2588 + 8.5278 + 0.0531 = 38.8397$$

The random effect used in the above model has a negligible impact on the fixed effect estimate but has a prominent role in the resulting standard error. This impacts the large standard error occurring in the results between clusters and the smaller standard error occurring in the effects within the cluster. There is a significant increase in the value of HDI in all the above models. Correlation structure analysis will be carried out in model 4 with different regions, regencies, or cities and at different times correlate 0, by the initial assumption that they are mutually independent.

$$\widehat{Corr}(Y_{ijk}, Y_{i*j*k}) = 0$$

Next, we will examine each of the same regions, regencies, or cities and at different times, have a correlation of 0.7791; this is a significant enough number to explain the diversity of variances from Model 4.

$$\widehat{Corr}(Y_{ijk}, Y_{ij*k*}) = \frac{\hat{\sigma}_{ID}^2}{\hat{\sigma}_{ID}^2 + \hat{\sigma}_{KK}^2 + \hat{\sigma}_{res}^2} = \frac{30.2588}{38.8397} = 0.7791$$

Then the latter will be studied in the same regions, the same regencies, or cities, and at different times it will correlate 0.9985 out of 1 so that it can be said to be highly associated with a positive correlation.

$$\widehat{Corr}(Y_{ijk}, Y_{ijk*}) = \frac{\hat{\sigma}_{ID}^2 + \hat{\sigma}_{KK}^2}{\hat{\sigma}_{ID}^2 + \hat{\sigma}_{KK}^2 + \hat{\sigma}_{res}^2} = \frac{30.2588 + 8.5278}{38.8397} = 0.9985$$

With Model 4, we continue the research on developing Model 4 by adding other independent variables, namely the average length of schooling, life expectancy, per capita income, the potential for conflict, and hydrometeorological disasters.

Although some models show significant results with large values in increasing HDI, we try to add independent variables to the model, either one variable, certain variables, or all variables. The first model to be given the independent variable is Model 5, with the addition of the average length of school (ALS) as the new independent variable. As seen from the standards provided by UNDP, namely the dimensions of life, one of which is education, we draw a hypothesis in the form of the variable ALS that significantly affects the value of HDI. This is similar to Models 6, 7, and 8, where each model adds the independent variables of life expectancy (LE), per capita income (PI), and expected length of schooling (ELS).

Table 6. Model 5 Test Results

	Value	Std. Error	p-value
Intercept	59.2112	2.7985	0.0000***
ALS	1.5311	0.2233	0.0000***
TIME	0.141	0.1145	0.2218
ALS: TIME	-0.0004	0.0127	0.9705

Table 6 shows that the p-value is very good, so it has a significant effect with a positive influence, which means that when the value of ALS goes up, the value of HDI also increases. With an increase in each ALS, it increases by 1 unit, so the value of HDI increases by 1.5311 units. Nevertheless, in this model, time and the interaction between time and ALS have no significant effect. In the real world, the more people who take formal education at the right time, the better their quality of life will be, which will immediately increase the value of HDI. Subsequent variables will be examined using other variables.

Table 7. Model 6 Test Results

	Value	Std. Error	p-value
Intercept	-88.6785	17.2592	0.0000***
LE	2.2334	0.2368	0.0000***
TIME	-2.7763	0.8381	0.0014***
LE: TIME	0.0358	0.0114	0.0024***

In Table 7, the variable LE significantly affects HDI positively because it has a significant p-value. The time variable here also has a significant negative impact. This means that the longer a person lives at the average age in Indonesia, the higher the HDI. Mathematically, it can be interpreted that LE increases by 1 unit, and the value of HDI increases by 2.2334 units. If it is returned to the real world, the longer people live, the more valuable things can be done to improve their quality of life. This is also supported by the fact that the interaction between time and LE significantly affects HDI. As the rate of life increases, HDI also increases. Model 7 is a model that adds per capita income, PI, in each region as the independent variable.

Table 8. Model 7 Test Results

	Value	Std. Error	p-value
Intercept	-28.2371	7.5301	0.0000***
PI	24.9667	1.7558	0.0000***
TIME	0.5424	0.5684	0.3428
PI: TIME	-0.066	0.1409	0.6407

It can be seen in Table 8 that PI in each region in West Java has a very significant effect on HDI. While the time and its interaction with PI are constant, increasing PI by 1 unit also increases the value of HDI by 24.9667 units significantly. This is a substantial enough number that can be used as a reference for increasing the value of HDI by raising PI in each region. The higher the income of West Java residents, the better their quality of life, so it can be noted that PI increases HDI significantly. The next model, Model 8, will be examined using the expected length of schooling (ELS) variable. It will be examined whether ELS affects HDI.

Table 9. Model 8 Test Results

	Value	Std. Error	p-value
Intercept	55.7856	7.1665	0.0000***
ELS	1.3082	0.4972	0.0102**
TIME	0.3101	0.3393	0.3636
ELS: TIME	-0.0017	0.0265	0.9502

By looking at Table 9, it can be concluded that ELS significantly affects HDI. With a positive influence, the result can be obtained that the greater the ELS years, HDI also increases, with an increase of 1.3082 units for ELS. In contrast, the time variable has no significant effect on HDI. If it is associated with phenomena in the field, there is greater hope that the old school will create quality human beings.

After looking at the independent variables, which are building elements of HDI value, which is a dimension of human life that has a significant effect, we try to look for other independent variables that are not included in the human life dimension, namely the number of hydrometeorological disasters (HD) and potential conflicts (PC), to determine whether they can affect HDI, from which we draw a hypothesis in the form of an HD and PC are negative things that can disrupt the process of human development. Model 9 is a model with the addition of the HD, and Model 10 is a model with the additional variable PC.

Table 10. Model 9 Test Results

	Value	Std. Error	p-value
Intercept	72.8678	3.96296	0.0000***
HD	-0.0008	0.00043	0.0415**
TIME	0.30768	0.02142	0.0000***
HD: TIME	0.00018	0.00019	0.3584

Table 11. Model 10 Test Results

	Value	Std. Error	p-value
Intercept	72.76419	3.92772	0.0000***
PC	-0.00023	0.00176	0.8949
TIME	0.28913	0.02836	0.0000***
PC: TIME	0.00123	0.00067	0.0717*

Tabel 10 states a significant negative relationship between HD and HDI. Although the effect is relatively small, equal to 0.0008, this proves that the initial research hypothesis regarding the negative effect of HD on HDI has been proven. In Model 9, TIME shows a positive and significant relationship to changes in HDI. The result shows that HDI in every regency or city in West Java generally shows an increasing trend of HDI. This is in line with the visual appearance of HDI data in Figure 1. Model 10 shows something slightly different. Even though PC has no statistically significant effect on HDI, the interaction between TIME and PC shows a positive and significant relationship with an alpha value of 10%. This positive relationship is fascinating to study because the effect of PC, when viewed as an independent variable (without interaction with other variables), has a positive effect on HDI, even though the effect is insignificant.

The 11th model will combine two independent variables. Previously, PC had no significant effect. These two variables are interesting to study. The significance of these two variables in the previous model occurs because the other variables are effects that have a direct impact on HDI. The results in Table 11 show more natural phenomena. PC and HD variables significantly affect HDI with various small and significant p-values. In HD, the effect is negative, while in PC, the effect is positive. The higher the number of HD, the lower the value of HDI, but vice versa. The higher the PC in the West Java area, the higher the value of HDI. The interaction between TIME and HD showed a positive relationship that was not statistically significant, but it was different from the interaction between PC and TIME, which showed a very significant positive relationship. This states that uncontrolled PC in each regency or city from time to time can reduce HDI value.

Table 12. Model 11 Test Results

	Value	Std. Error	p-value
Intercept	73.05576	3.965748	0.0000***
HD	-0.00356	0.000837	0.0000***
PC	0.005666	0.002352	0.0185**
TIME	0.312645	0.024407	0.0000***
HD: TIME	0.000569	0.000300	0.6016
PC: TIME	-0.003444	0.001107	0.0026***

CONCLUSIONS AND SUGGESTIONS

This study provides an overview and explanation of the variables that can affect the HDI from different perspectives so that the government, stakeholders, and the entire community can prepare themselves and develop targets or work programs in the form of optimizing the determinants of the human development index from dimensions other than the social dimension of society.

Based on the modeling results, almost all models contain variables that significantly affect the human development index. The dimensions of human life, namely life expectancy, average length of schooling, expected length of education, and per capita income, are the model-building variables that show significant positive results on the human development index. In addition to the dimensions of human life, other factors can affect the human development index, namely the number of hydrometeorological disasters and potential conflicts, which have a negative correlation, so that the value of the human development index can be reduced if the intensity of hydrometeorological disasters increases and possible conflicts can be controlled. This research can be enhanced with the other variables that might impact or describe the human development index for future research.

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