

Analysis of Road Infrastructure and Fuel Oil Consumption on Economic Growth in Indonesia: An ARDL Model Approach

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Abstract

This study aims to analyze the effect of road length and fuel oil consumption on economic growth in Indonesia. The data used are time series data covering the period 2005–2023, obtained from Badan Pusat Statistik and the Indonesian Oil and Gas Statistics published by the Ministry of Energy and Mineral Resources. The analytical method employed is the Autoregressive Distributed Lag (ARDL) model. The estimation results indicate that in the short run, road length has a negative effect on economic growth, while fuel consumption has a positive effect. However, in the long run, road length positively influences economic growth, whereas fuel consumption has a negative impact.

Keywords: *Economic Growth, Road Length, Fuel Consumption*

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Introduction

Economic development, energy efficiency, and environmental protection are among the most prioritized issues by policymakers and environmental scientists worldwide. Economic growth is closely linked to increased energy use [1]. As an indicator of development, economic growth is characterized by increased economic activity and is reflected in the growth of Gross Domestic Product (GDP). Growth is inseparable from the role of adequate infrastructure and energy needs. Infrastructure development supports various production processes [2] and also increases the capacity of small regions. Sometimes political factors also influence infrastructure development choices [3].

Several infrastructure networks, such as transportation, telecommunications, electricity, natural gas and oil, and water distribution, are interdependent to function optimally [4]. One infrastructure that plays a crucial role in supporting growth is transportation infrastructure [5], namely roads. The existence of roads supports the mobility of labor, goods, and services, which impacts the efficiency of economic activities and expands market access.

In Indonesia, road infrastructure is a priority for creating connectivity between regions. The availability of roads encourages increased economic activity and accelerates national economic growth. Good road infrastructure also contributes to increased productivity in economic sectors such as trade, industry, agriculture, and tourism, as well as cost efficiency, industrial agglomeration, regional distribution, and environmental changes [6]. Although numerous studies have examined the causal relationship between transportation infrastructure and economic growth [7], a comprehensive and systematic literature review on this topic is currently lacking [8].

On the other hand, increased economic activity and transportation mobility are also accompanied by increased energy demand, particularly for fuel oil. Oil consumption is one indicator of a country's level of economic activity. Faster economic growth and a larger workforce will increase oil demand [9].

For Indonesia, as a developing country with a vast geographical area and a large population, the link between transportation infrastructure and fuel consumption is crucial. Increasingly developed road infrastructure will increase vehicle mobility and goods distribution, ultimately increasing fuel consumption [10]. This increase in energy consumption can reflect increased economic activity, contributing to economic growth [11]. Previous studies on transportation infrastructure development and economic growth have empirical results showing that transportation infrastructure has a driving influence on sustainable economic growth [12].

Based on time series data released by the Central Statistics Agency (BPS), the overall growth in road length in Indonesia from 2004 to 2023 shows a fairly consistent upward trend. This demonstrates the government's commitment to strengthening transportation infrastructure to improve regional connectivity and support national economic growth.

Overall, this increase represents growth of approximately 47.7% over a 19-year period. Calculated using the average annual growth rate (trend growth rate), Indonesia's road length is growing at approximately 2.0% per year. This growth demonstrates the government's ongoing efforts to expand its transportation infrastructure network to improve regional connectivity.

The relationship between infrastructure development, fuel consumption, and growth is not always straightforward. While road construction will boost growth by facilitating the movement of goods and services, it will also drive fuel consumption and increase CO₂ emissions, impacting the environment.

In 2023, Indonesia will rank 15th in world primary energy consumption, up from 20th in 2005 [13]. In addition, rising fuel prices will affect the transportation and industrial sectors. Dependence on fossil fuels and the ongoing oil crisis also affect global industrial development, leading to economic activity being one of the reasons for seeking renewable energy to reduce dependence on oil, but in reality, dependence is actually increasing [14]. Based on this

background, this study aims to analyze the influence of road infrastructure and fuel consumption on economic growth in Indonesia.

Literature Review

This study is based on neoclassical economic theory proposed by [15]. Solow views transportation infrastructure development alongside various other factors that cannot be directly observed, such as technological progress and policies, which are then reflected in the residual component representing technological progress. The theory of endogenous economic growth developed by [16] emphasizes that externalities resulting from infrastructure investment are one of the main sources driving long-term economic growth.

A study of the relationship between transportation infrastructure development and economic growth in the UK by [17] considered various time periods. The Principal Component Analysis (PCA) method was used to construct a composite indicator representing the level of transportation infrastructure development. Furthermore, this study applied the Vector Error Correction Model (VECM) to examine the long-term and short-term relationship between transportation infrastructure development and economic growth during the period 1970–2017. The results showed that in the long term, transportation infrastructure development had a positive effect on economic growth. However, in the short term, the impact tended to be significantly negative.

The development of new transportation infrastructure can attract companies with high transportation usage intensity to locate in an area, while simultaneously encouraging the reorganization of production processes in existing companies [5].

Many studies on oil consumption and economic growth [18][19], [20]. A study by [21] where the data used is an annual time series of Pakistan during the period 1972–2016 by applying the Autoregressive Distributed Lag (ARDL) Bounds Test method obtained oil consumption in the transportation sector, gas consumption in the fertilizer and power generation sectors, and electricity consumption in the industrial sector have a positive and significant influence on economic growth in the long term.

Furthermore, [22] used real Gross Domestic Product (GDP) per capita as an indicator of economic growth, while energy consumption was represented by four sub-variables, namely electricity, oil, natural gas, and coal. Using panel data for the period 1969–2009, this study applied the Pedroni Cointegration Test approach to test cointegration, as well as the two-stage procedure of the Engle–Granger Two-Step Method to analyze causality relationships in the short and long term. The results showed that oil consumption in the industrial and transportation sectors, gas consumption in the fertilizer and power generation sectors, and electricity consumption in the industrial sector had a positive and significant influence on economic growth in the long term. Conversely, oil consumption in the agricultural and power generation sectors, coal consumption in the power generation and brick kiln industry sectors, gas consumption in the cement sector, and electricity consumption in the agricultural sector had a negative and significant influence on economic growth.

Research on oil consumption and economic growth shows an inverted-U relationship using panel data analysis with a fixed effect or random effect model, using data from 61 countries during the period 1990–2008. It was found that an inverted-U relationship between oil consumption and GDP per capita was statistically significant, meaning that oil consumption per capita increased at a slower rate along with the increase in GDP per capita until it reached a peak, after which consumption would decline [23].

Research Methodology

The fuel consumption structure in Indonesia consists of aviation turbine gasoline, aviation gasoline, RON 88 gasoline/Gasoline 88, RON 92 gasoline/Gasoline 92, kerosene, diesel oil, and fuel oil/DCO/IFO/MFO for household, transportation, industrial, and electricity use. Data from 2005 to 2023 were obtained from the website of the Indonesian Central Bureau of Statistics. Data on road length and fuel consumption were obtained from the Indonesian Oil and

Gas Statistics publication published by the Ministry of Energy and Mineral Resources. The independent variables were road length (national and provincial roads) and fuel consumption, using domestic fuel sales as a proxy. The dependent variable was economic growth, using Indonesia's GRDP at constant prices as a proxy.

The ARDL (Auto Regressive Distributed Lag) model used in this study is expected to provide an effective analysis of the influence of road length and fuel consumption for the period 2005-2023.

The ARDL equation model is as follows:

$$\Delta PE = \alpha_0 + \sum_{i=1}^n \Delta PE_{t-1} + \sum_{i=1}^n \alpha_{1i} \Delta PJ_{t-1} + \sum_{i=1}^n \alpha_{2i} \Delta KBM_{t-1} + \beta_1 PJ_{t-1} + \beta_2 PJ_{t-1} + e_t$$

Description:

- Δ = lag
- PE = economic growth
- PJ = road length
- KBM = fuel consumption
- $\alpha_{1i} - \alpha_{2i}$ = short-term dynamic relationship
- $\beta_1 - \beta_2$ = long-term dynamic relationship
- e = error

Before estimating the ARDL model, several tests must first be carried out, namely the stationary test, optimal lag, and cointegration test with the help of the Eviews 13 program.

Results

1. Stationarity Test

The stationarity test, or unit root test, uses the Augmented Dickey-Fuller (ADF) test. This test is performed to avoid invalid relationships between variables, ensuring that the estimated model has economic meaning.

Table 1. Stationarity Test

Variabel	Level		First Difference		Keterangan
	T-statistic	Prob	T-statistic	Prob	
PE	-0.793375	0.7968	-3.938897	0.0090	I(1)
PJ	-4.876944	0.0013	-2.410291	0.1536	I(0)
KBM	-2.492699	0.1334	-5.520670	0.0004	I(1)

Source: Eviews Data Processing Results 13, 2026

Based on the results of the one-by-one test of the three variables, the results for the economic growth (PE) variable are stationary at the level level, while for the road length and fuel consumption variables, they are stationary at the First Difference with a probability value of less than 0.05, so it can be concluded that the three variables are stationary. These results indicate that the data can be used to be applied for processing with the ARDL estimation model.

2. Cointegration Test

Because all variable data meets the stationary test, a cointegration test is performed to determine whether cointegration occurs between the long-term and short-term dependent and independent variables. If F-statistic > I(1) → cointegration is present; if F-statistic < I(0) → no cointegration is the rule in making decisions based on the bound test results.

Table 2. Bound Cointegration Test Results

Test Statistic	Value
F-statistic	14.466820

Sample Size	10%		5%		1%	
	I(0)	I(1)	I(0)	I(1)	I(0)	I(1)
30	2.915	3.695	3.538	4.428	5.155	6.265
Asymptotic	2.630	3.350	3.100	3.870	4.130	5.000

* I(0) and I(1) are respectively the stationary and non-stationary bounds.

Source: Eviews Data Processing Results 13, 2026

Based on the table above, the F statistic is greater than the upper and lower critical value at all levels of significance ($14.466 > 4.428$ at a significance level of 5%), so H_0 is rejected and H_1 is accepted that the model meets the cointegration requirements, namely that the road length (PJ) and fuel consumption (KBM) variables together have a long-term relationship with economic growth (PE).

3. Optimal Lag Model

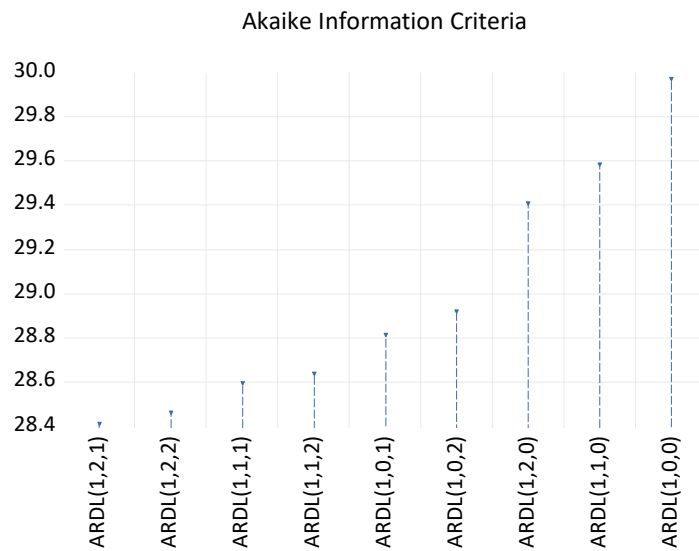


Figure 1. Optimal Lag Model

Based on the Akaike Information Criteria (AIC) value graph, it can be seen that there is variation in the AIC value for each lag combination in the ARDL model tested. The model with the smallest AIC value is the most optimal model, namely (1,2,1).

4. ARDL Model Estimation

The ARDL (Autoregressive Distributed Lag) model is a dynamic model that shows the influence of road length (PJ) and fuel consumption (KBM) over time, including the influence of past economic growth on current economic growth.

Table 3. ARDL Estimation Results

Variable	Coefficient	Std. Error	t-Statistic	Prob.*
PE(-1)	0.650627	0.154404	4.213803	0.0018
PJ	-26.77324	16.01100	-1.672178	0.1254
PJ(-1)	12.01889	16.42347	0.731811	0.4811
PJ(-2)	35.58248	19.06529	1.866349	0.0916
KBM	0.025500	0.013866	1.839093	0.0957
KBM(-1)	-0.072823	0.016110	-4.520263	0.0011
C	-3628580.	4621876.	-0.785088	0.4506

Source: Eviews Data Processing Results 13, 2026

Based on the ARDL (1,2,1) model estimation results, it was found that the economic growth variable in the previous period had a positive and significant effect on current economic growth. This indicates an inertial effect on economic growth. The road length variable showed an insignificant effect in the short term, but tended to have an impact after several periods. Meanwhile, fuel consumption showed a variable effect, with a significant effect appearing in the lag period.

The R² value obtained is 0.9955, meaning that approximately 99.55% of the variation in economic growth (PE) can be explained by the road length (PJ) and fuel consumption (KBM) variables in the model. The F-statistic probability value of 0.000000, which is smaller than the 5% significance level, indicates that simultaneously the road length and fuel consumption variables have a significant effect on economic growth. Thus, the model used is worthy of further analysis. Short-term and long-term estimates using the ARDL model are presented in Tables 4 and 5.

Table 4. Short-term Estimates using the ARDL Model

Variable	Coefficient	Std. Error	t-Statistic	Prob.
COINTEQ*	-0.349373	0.040281	-8.673377	0.0000
D(PJ)	-26.77324	7.175232	-3.731342	0.0025
D(PJ(-1))	-35.58248	12.04557	-2.953989	0.0112
D(KBM)	0.025500	0.007632	3.341199	0.0053

Source: Eviews Data Processing Results 13, 2026

Based on the results of testing the short-term model with ARDL in the table, it has the following equation:

$$\Delta PE_t = -0.349ECT_{t-1} - 26.77\Delta PJ_t - 35.58\Delta PJ_{t-1} + 0.0255\Delta KBM_t$$

The error correction term (ECT) coefficient is -0.349373 and is significant at the 1% level, indicating the existence of an adjustment mechanism towards long-term equilibrium. This means that approximately 34.9% of the imbalance will be corrected in one period. In the short term, the road length variable has a negative and significant effect on economic growth, both in the current and previous periods. This indicates that short-term road infrastructure development has not had a positive impact on economic growth. Meanwhile, the fuel consumption variable has a positive and significant effect on economic growth in the short term, indicating that increased energy consumption drives economic activity.

Table 5. Long-Term Estimates of the ARDL Model

Variable *	Coefficient	Std. Error	t-Statistic	Prob.
PJ(-1)	59.61577	12.88596	4.626414	0.0004
KBM(-1)	-0.135449	0.126139	-1.073807	0.3011
C	-10385987	9913469.	-1.047664	0.3125

Source: Eviews Data Processing Results 13, 2026

Based on long-term testing with the ARDL table above, the equation is:

$$PE = 59.61577PJ - 0.135449KBM - 10,385,986.72$$

The road length variable has a positive and significant effect on economic growth, with a coefficient of 59.61577. This indicates that long-term improvements in road infrastructure can drive economic growth. Meanwhile, fuel consumption has a negative but insignificant coefficient, indicating that fuel consumption has no significant effect on economic growth in the long term.

5. Classical Assumption Test

Normality Test

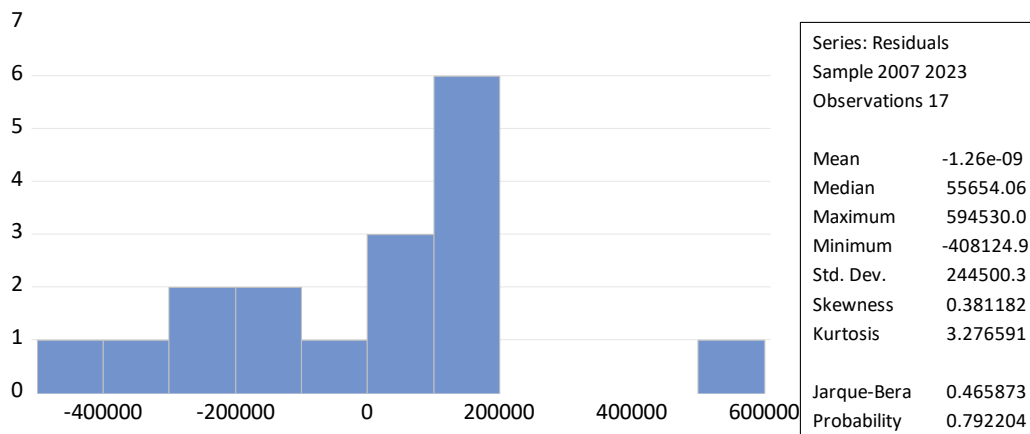


Figure 2. Normality Test Results

Based on the Jarque-Bera normality test, a probability value of 0.792204 was obtained, which is greater than 0.05. This indicates that the residuals are normally distributed. Thus, the normality assumption in the model has been met, making the model suitable for further analysis.

Autocorrelation Test

Table 6. Autocorrelation Test Results

Breusch-Godfrey Serial Correlation LM Test:

Null hypothesis: No serial correlation at up to 2 lags

F-statistic	2.016283	Prob. F(2,8)	0.1954
Obs*R-squared	5.697340	Prob. Chi-Square(2)	0.0579

Source: Eviews Data Processing Results 13, 2026

Obs*R-squared value > Based on the Breusch-Godfrey Serial Correlation LM Test, the probability values obtained were 0.1954 (F-statistic) and 0.0579 (Chi-Square), which are greater than the 5% significance level. This indicates that the model does not contain autocorrelation. However, the Chi-Square probability value is close to the significance limit, so these results need to be interpreted with caution. 0.05 means there is no autocorrelation

Heteroscedasticity Test

Table 7. Heteroscedasticity Test Results

Heteroskedasticity Test: Breusch-Pagan-Godfrey

Null hypothesis: Homoskedasticity

F-statistic	0.350958	Prob. F(6,10)	0.8937
Obs*R-squared	2.957087	Prob. Chi-Square(6)	0.8142
Scaled explained SS	1.164720	Prob. Chi-Square(6)	0.9786

Source: Eviews Data Processing Results 13, 2026

Based on the heteroscedasticity test, probability values of 0.8937 (F-statistic), 0.8142 (Obs*R-squared), and 0.9786 (Scaled explained SS) were obtained, all of which were greater than the 5% significance level. This indicates that the model does not experience heteroscedasticity problems, so the residual variance is constant and the model is suitable for use.

6. Model Stability Test

The structural stability of the model using the Cumulative Sum of the Recursive Residuals (CUSUM) shows that the CUSUM line deviates from the critical limit at the 5% significance level.

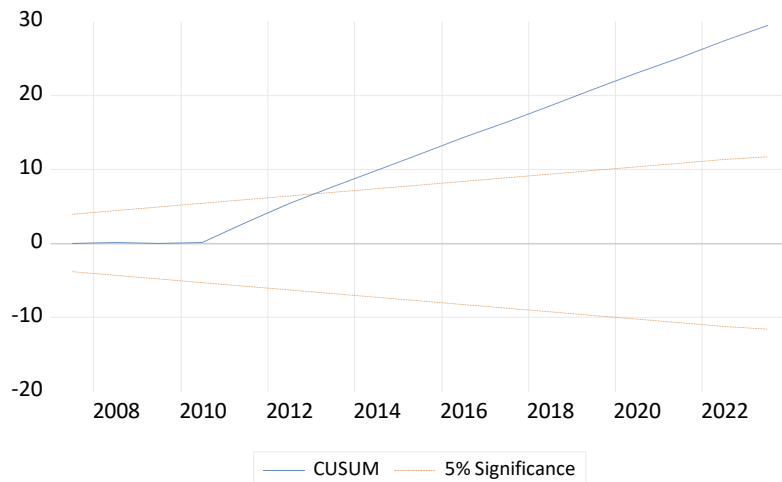


Figure 3. Stability of the Cusum Model

Based on the figure, it can be seen that the model was not parameter-stable during the study period. This condition is caused by changes in the base year in the GRDP calculation.

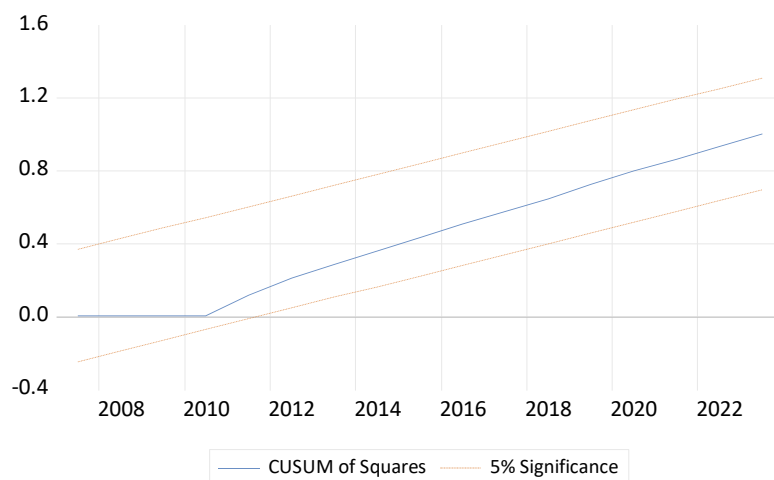


Figure 4. Stability of the CUSUMQ Model

The CUSUMQ line consistently remains within the 5% limit. None of the lines cross or cross the red line. This indicates that the ARDL model used is parameter-stable throughout the observation period (2007–2023). Therefore, even though the CUSUM model is not yet stable, the estimation results can still be used with caution in interpretation.

In the short term, the road length (PJ) variable for both the current and previous periods has a negative coefficient of -26.77 and -35.58, respectively. This indicates that short-term increases in road length are accompanied by a decline in economic growth. This condition may be caused by a time lag in infrastructure utilization, where initial road construction does not immediately have a positive impact on economic activity.

Meanwhile, fuel consumption (KBM) has a positive coefficient of 0.0255, indicating that short-term increases in fuel consumption can boost economic growth. This is explained by the fact that increased energy use reflects increased economic activity, such as production and transportation. Long-term fuel consumption (KBM) has a negative effect on economic growth, with a coefficient of -0.135. This indicates that high dependence on fuel consumption can burden the economy, for example through increased production costs or inefficient energy use.

This highlights the importance of policies that focus not only on infrastructure development but also on efficient energy use for sustainable economic growth.

The results of this study can be explained using the neoclassical economic growth theory proposed by Robert Solow. In Solow's model, economic growth is influenced by the accumulation of capital, labor, and technological progress. In the context of this research, road length (PJ) can be viewed as part of physical capital (infrastructure) that plays a role in increasing economic productivity. Long-term estimates indicate that PJ has a positive effect on economic growth. This aligns with Solow's theory, which states that increasing the capital stock will increase output in the long run.

However, in the short term, PJ actually shows a negative impact on economic growth. This phenomenon is consistent with the Solow framework, as the capital accumulation process involves an adjustment phase. In the early stages of infrastructure development, large investment costs are not immediately followed by increased output, so the impact on economic growth can be negative in the short term. Furthermore, the fuel consumption (KBM) variable can be linked to energy use in the production process. In the Solow model, energy is not explicitly included as a primary variable, but it can be considered a supporting factor influencing production efficiency.

Conclusion

In the short term, road length has a negative and significant effect on economic growth. This indicates that road infrastructure development does not immediately have a positive impact due to the time lag in its utilization and the high initial investment costs. Meanwhile, fuel consumption has a positive and significant effect on economic growth in the short term, reflecting that increased energy use drives economic activities such as production and transportation. In the long term, road length has been shown to have a positive and significant impact on economic growth. This indicates that road infrastructure development can improve connectivity, distribution efficiency, and economic productivity sustainably. Conversely, fuel consumption has a negative but insignificant impact on long-term economic growth, indicating that dependence on fossil fuels tends not to contribute optimally to economic growth.

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