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Statistical Approach in Analyzing Fuel Efficiency of Diesel SUVs in Indonesia Using MATLAB

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Abstract

The scarcity of fossil fuels and the rising environmental concerns make improving fuel efficiency in the automotive sector a critical focus. Diesel Sport Utility Vehicles (SUVs) in Indonesia, known for their high fuel consumption, significantly contribute to these challenges. This research addresses the problem by investigating the factors influencing fuel efficiency in diesel SUVs available in the 2024 Indonesian market. The primary objective is to analyze the impact of engine torque, vehicle weight, and engine capacity on fuel consumption. To achieve this, we employed MATLAB as a tool for statistical analysis, using specific algorithms such as linear regression, box plot, and correlation methods to model and evaluate the data. The study found that vehicle weight and engine capacity show a strong positive correlation with fuel consumption, indicating that larger engines and heavier vehicles consume more fuel. In contrast, engine torque was found to have a weaker correlation, suggesting that factors like aerodynamics and transmission efficiency may play a more significant role. These results provide valuable insights for manufacturers in designing more fuel-efficient SUVs and for consumers making informed purchasing decisions. Ultimately, this research contributes to the development of more sustainable transportation solutions by highlighting the importance of optimizing vehicle design and engine specifications to reduce fuel consumption in the near term.

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1. Introduction

Indonesia faces significant pressure to reduce its reliance on fossil fuels due to extensive vehicle use, particularly in private transportation. According to the Institute for Essential Services Reform (IESR) and BPS-Statistics Indonesia, fuel consumption in Indonesia rose from 30.41 to 30.57 kiloliters between 2015 and 2020 [1]. Over this same period, the number of motor vehicles increased by 77.35% [2]. This rising fuel consumption places an economic burden on the country due to high oil import costs and exacerbates environmental issues, primarily through greenhouse gas emissions that contribute to climate change.

In response, Indonesia must explore alternative energy sources, such as electric vehicles and biofuels, as several studies suggest [3]–[5]. However, in the short term, enhancing the fuel efficiency of conventional cars, particularly diesel-powered Sport Utility Vehicles (SUVs), remains essential. Diesel SUVs are widely used in Indonesia but are known for high fuel consumption, making them significant contributors to the country's fuel demand and environmental footprint.

Several critical factors influence fuel efficiency in SUVs, including aerodynamic design, vehicle weight, engine efficiency, and transmission technology. Aerodynamic improvements, such as optimizing windshield angles and adding features like vortex generators and rear spoilers, can significantly reduce drag and enhance fuel efficiency, especially at higher speeds [6]–[8]. Additionally, reducing vehicle weight through optimized body structures and lighter materials has proven effective in lowering fuel consumption [9]. Engine efficiency and transmission technology are also essential factors; optimizing these systems for real-world driving conditions can lead to further fuel savings [10]–[13]. Studies using advanced computational fluid dynamics (CFD) simulations and wind tunnel tests show that improving both aerodynamics and powertrain systems is critical to enhancing fuel efficiency [14].

Despite considerable research on the effects of individual factors such as aerodynamics and vehicle weight on fuel efficiency, few studies have comprehensively analyzed the combined effects of engine torque, thrust force, and vehicle weight on the fuel consumption of diesel SUVs in Indonesia. Existing research often focuses on singular factors or relies on global data, creating a gap in understanding the specific market conditions of Indonesian SUVs. Moreover, statistical analysis using tools like MATLAB to explore these variables in combination is limited, providing an opportunity to address this gap. This study aims to bridge that gap by conducting a detailed statistical analysis using MATLAB to assess the influence of engine torque, thrust force, and vehicle weight on the fuel consumption of 2024 model diesel SUVs in Indonesia [15]. Employing linear regression, box plots, and correlation methods, the study offers a comprehensive evaluation of the critical factors affecting fuel efficiency.

Our findings indicate that vehicle weight has the strongest positive correlation with fuel consumption, confirming that heavier vehicles tend to consume more fuel. In contrast, engine torque and thrust force show a weaker correlation, suggesting that factors like aerodynamics and transmission efficiency play a more dominant role in fuel efficiency. These results provide valuable insights for manufacturers aiming to optimize vehicle design and for consumers seeking fuel-efficient SUVs. The study contributes to strategies for reducing fuel consumption, supporting Indonesia's progress toward sustainable transportation.

2. Methods

This study utilizes mathematical modeling and statistical analysis in MATLAB to examine the effects of engine capacity, torque, vehicle weight, and engine technology on the fuel efficiency of diesel SUVs sold in Indonesia in 2024. The analysis covers various diesel SUV models produced between 2023 and 2024, with engine capacities ranging from 1989 to 2694 cc. A quantitative research approach is employed to assess the impact of these technical factors on fuel consumption. The research process is structured as follows [16]–[19]:

2.1. Data collection

Data were collected from multiple sources, including technical specifications for diesel SUV models produced between 2023 and 2024. The dataset includes key variables such as engine capacity, vehicle weight, engine torque, and fuel consumption rates. Fuel consumption data were primarily sourced from existing literature and manufacturer specifications.

2.2. Software and tools

MATLAB was used for data analysis, specifically the Statistical Toolbox within MATLAB. This toolbox enabled the study to conduct linear regression, Pearson correlation analysis, and other relevant statistical tests to evaluate the relationships between variables [16], [17]. Using MATLAB facilitated precise modeling of how fuel consumption is influenced by factors such as engine capacity, vehicle weight, and torque [20]–[23].

2.3. Analysis procedure

The analysis followed a structured approach, starting with scatter plot analysis to visually examine relationships between fuel consumption and independent variables (engine capacity, vehicle weight, and torque). Linear regression models were then constructed to quantify the effects of these variables on fuel consumption, and Pearson correlation coefficients were calculated to determine the strength and direction of these relationships.
The steps involved in the analysis were as follows:

A. Scatter plot analysis

This step visually represented the relationships between the independent variables (engine capacity, vehicle weight, and torque) and fuel consumption, providing an initial understanding of potential correlations.

B. Linear regression

Linear regression models were developed to quantify the impact of engine capacity, vehicle weight, and torque on fuel consumption. This analysis provided a detailed assessment of how variations in these variables affect fuel efficiency.

C. Correlation coefficients

Pearson correlation coefficients were calculated to measure the strength and direction of the linear relationships between variables. These coefficients offered insights into how engine capacity, vehicle weight, and torque correlate with fuel consumption [22], [23].

3. Results and Discussion

Figure 1 illustrates the relationship between fuel consumption and key factors. Figure 1(a) displays scattered data, indicating a weak correlation between engine capacity and fuel consumption, suggesting that engine capacity is not a significant predictor of fuel consumption. In contrast, Figure 1(b) reveals a moderate correlation between vehicle weight and fuel consumption, though it is not the sole determining factor. Additionally, the second subplot in Figure 1(b) shows a clear positive correlation between vehicle weight and fuel consumption, supporting the hypothesis that heavier vehicles tend to consume more fuel. This finding highlights the importance of reducing vehicle weight to enhance fuel efficiency. However, in Figure 1(a), the lack of a linear relationship suggests that engine capacity is not a significant predictor of fuel consumption.

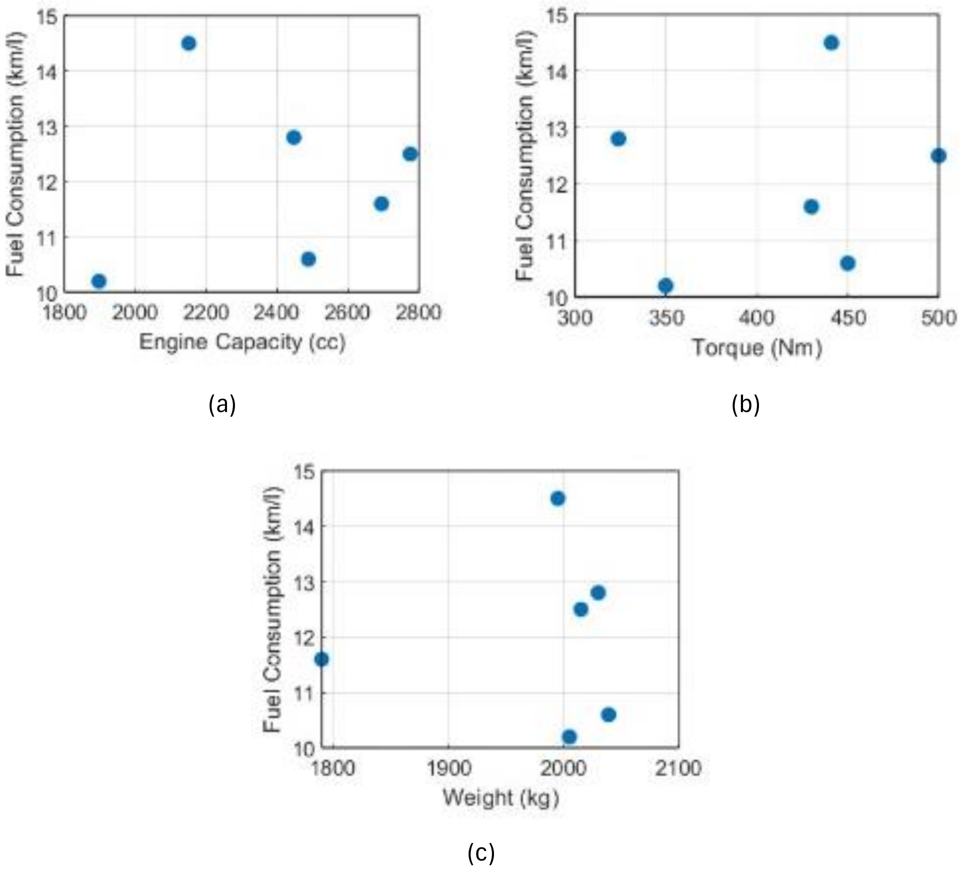


Figure 1. Relationship between fuel consumption and engine capacity (a), fuel consumption and torque (b), and fuel consumption and vehicle weight (c)

Figure 2 presents the histogram distribution of various vehicle variables, revealing several notable patterns that enhance our understanding of SUV characteristics and their impact on fuel consumption. The histogram for engine capacity indicates that most SUVs in the dataset have engines in the 2000 to 3000 cc range, suggesting a standardized balance between power and efficiency. This range raises questions about whether these engine sizes align with optimal fuel efficiency practices. Further investigation could provide insights into potential engine size optimizations to enhance fuel efficiency without sacrificing performance, a key consideration for automotive engineers and researchers. Figure 2(a) illustrates that most SUVs have a fuel consumption rate of around 12 km/l, with some achieving higher efficiency near 14 km/l. These differences may be influenced by factors such as engine capacity or vehicle weight.

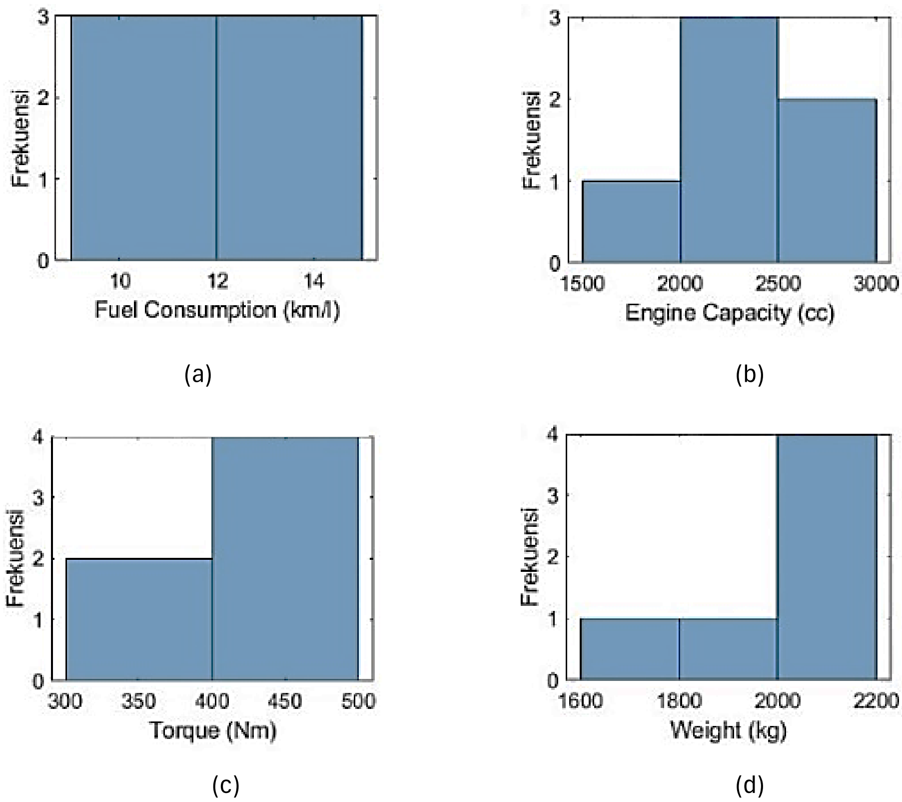


Figure 2. The histogram distribution of various variables fuel consumption histogram (a), machine capacity histogram (b), torque histogram (c), and weight histogram (d)

Furthermore, Figure 2(b) indicates that most SUVs in the Indonesian market have engine capacities primarily in one of two categories: 2000 cc and 2600 cc. This likely reflects variations in design strategies among manufacturers, with smaller engines being optimized for fuel efficiency, while larger engines prioritize performance. The histogram for engine capacity reveals an interesting trend. Most vehicles have an engine capacity between 2000 and 3000 cc, indicating this range as typical for SUVs in the dataset. The prevalence of vehicles within this range suggests a standardization in engine size that balances power and efficiency. However, it would be useful to explore whether these capacities align with the best fuel efficiency practices or if there are opportunities for optimizing engine size further. This investigation could potentially lead to insights into how to strike a better balance between fuel efficiency and performance, a crucial aspect for our audience of automotive engineers and researchers.

Figure 2(c) shows that engine torque in most SUVs ranges between 350 and 450 Nm, providing these vehicles with considerable power for towing or navigating challenging terrains. This suggests that increased torque may be directly associated with vehicle performance in scenarios involving tough terrain or heavy loads. The torque distribution is divided into two main intervals, with the majority of vehicles having torque values between 400 and 500 Nm. This split suggests that there are two predominant categories of engines being used, which could be associated with different performance requirements or design philosophies. The presence of these two groups indicates a possible trade-off between high-torque engines for performance and lower-torque engines for fuel efficiency.

Figure 2(d) illustrates that vehicle weight significantly impacts fuel consumption. Heavier SUVs generally require more energy and fuel to operate, which can reduce fuel efficiency. In this dataset, most SUVs weigh close to 2000 kg, a factor that likely influences their fuel consumption rates. The vehicle weight distribution shows that most vehicles weigh between 1800 and 2200 kg, with the highest frequency occurring in the 2000 to 2200 kg range. This indicates that the majority of the SUVs in the study fall within this weight class, likely due to design choices that balance durability and performance with fuel efficiency.

In the torque distribution, the data shows a clear division into two main intervals, with most vehicles having torque values between 400 and 500 Nm. This split suggests that manufacturers may target different performance levels, with some engines prioritizing higher torque for enhanced performance and others focusing on fuel efficiency. These two groups reflect a potential trade-off between high-torque engines and fuel-efficient designs. The vehicle weight distribution indicates that most SUVs in the dataset weigh between 1800 and 2200 kg, with the highest frequency in the 2000 to 2200 kg range. This concentration likely reflects design choices aimed at balancing durability, safety, and performance while maintaining reasonable fuel efficiency. The implications of this weight distribution for fuel consumption are significant, as heavier vehicles generally require more fuel, consistent with the trends observed in our study.

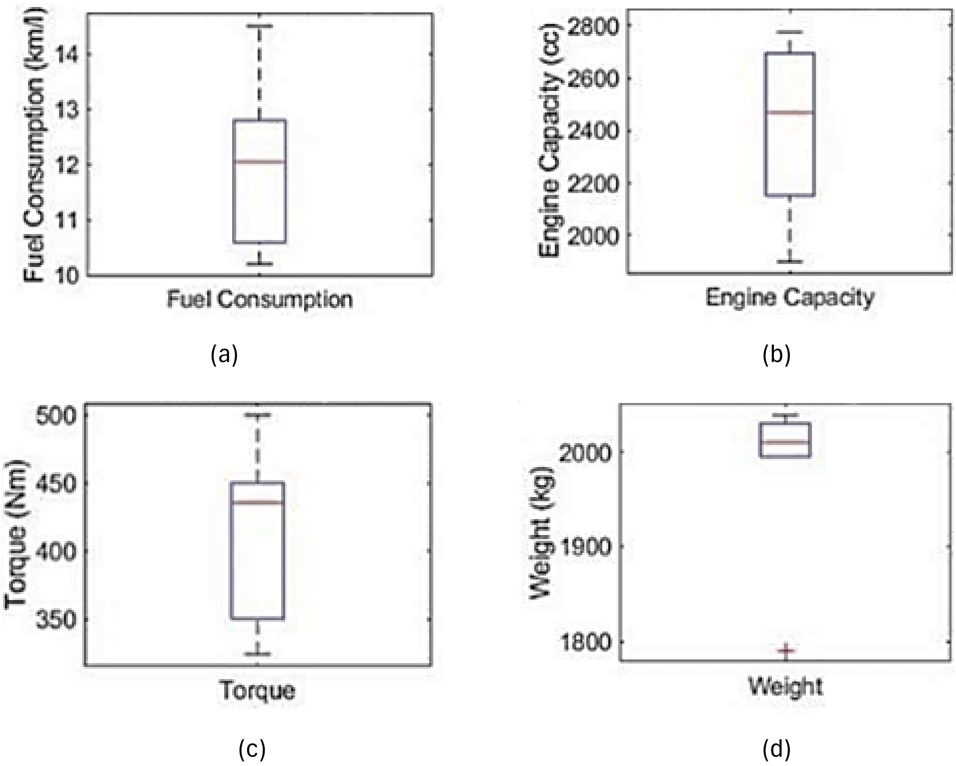


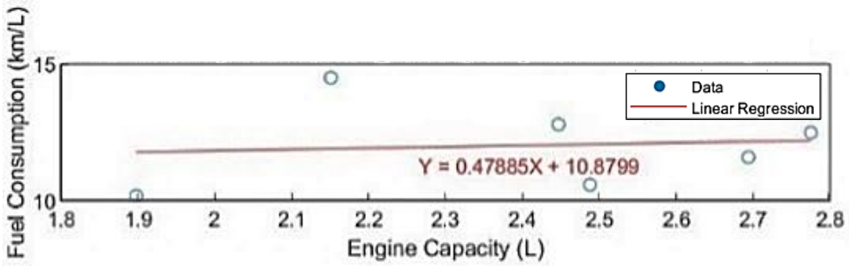
Figure 3. Box plot graph of fuel (a), engine (b), torque (c), and vehicle weight (d)

Figure 3 presents box plots for fuel consumption, engine capacity, torque, and vehicle weight, offering valuable insights into the analysed SUV characteristics. The fuel consumption box plot shows a relatively symmetric distribution, with a median value of around 12 km/l, indicating that most vehicles have moderate fuel efficiency. The interquartile range (IQR) reflects some variability. At the same time, the presence of outliers suggests that a few vehicles deviate significantly from the norm, either consuming more fuel than the average. These outliers may result from factors such as unique driving conditions, vehicle maintenance differences, or technology variations. Identifying these outliers is important for understanding the extremes in fuel efficiency and can provide insights into areas for potential improvement.

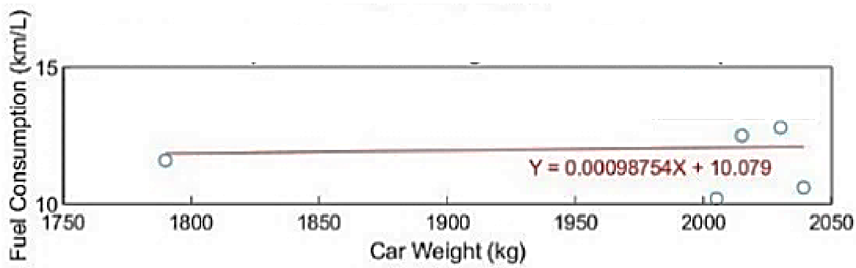
We observe a wide range of values in the engine capacity box plot, with a median of approximately 2600 cc. This diversity in engine capacities highlights the variety of performance and efficiency needs catered to by different SUV models. The wide IQR underscores the variation in engine sizes, reflecting different market preferences and performance demands. This variation suggests that manufacturers are designing SUVs with various engine capacities to target different segments, balancing power and efficiency according to consumer needs.

The torque distribution also shows significant variability, with a median of around 425 Nm and a broad IQR. This variation indicates that SUVs in the dataset are equipped with engines designed for various performance levels, from high-torque engines prioritizing power to lower-torque engines focusing on fuel efficiency. Outliers in the torque distribution highlight vehicles with exceptionally high or low torque, which could have implications for both performance and fuel consumption. This variability suggests that manufacturers optimize torque based on the intended use of the SUV, whether for performance or efficiency.

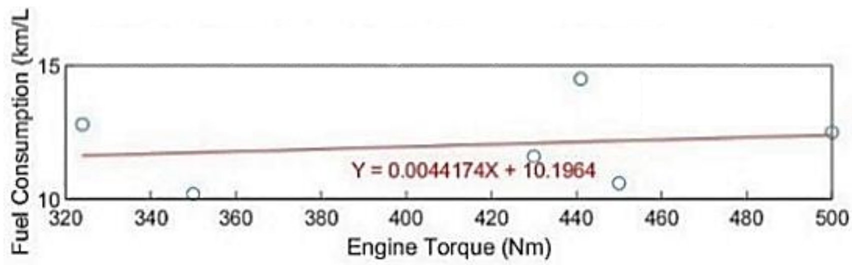
Finally, the vehicle weight box plot reveals that most SUVs weigh between 1800 and 2200 kg, with a median of around 2000 kg. The relatively narrow IQR indicates that most vehicles fall within a similar weight range, consistent with standard design practices prioritizing durability, safety, and performance. However, one notable outlier with significantly lower weight points to the presence of a vehicle specifically designed for weight reduction, likely aimed at enhancing fuel efficiency. This finding reinforces the importance of weight as a factor in fuel consumption, as reducing vehicle weight can improve efficiency without sacrificing performance.



(a)



(b)



(c)

Figure 4. The analysis describes the relationship between engine capacity and consumption (a), the relationship between car weight and fuel consumption (b), and the relationship between engine torque and fuel consumption (c)

The regression analysis in Figure 4 illustrates the relationships between fuel consumption and three key variables: engine capacity, vehicle weight, and engine torque. The first subplot shows a linear regression between engine capacity and fuel consumption, revealing a positive correlation. The regression equation Y= 0.00098754 X+10.079 (X: Car Weight (kg). Y: Fuel Consumption (km/l)) indicates that fuel consumption tends to rise as engine capacity increases. This relationship is understandable, as larger engines generally require more fuel to generate greater power. This positive correlation underscores the importance of optimizing engine size to balance power needs with fuel efficiency, especially in SUV design.

Figure 4(b) analyzes the relationship between vehicle weight and fuel consumption. The regression line, defined by the equation Y=0.47885 X+10.8799Y (X : Engine Capacity (L), Y : Fuel Consumption (km/l)), shows a moderate positive correlation, suggesting that heavier vehicles consume more fuel. This finding aligns with the basic principle that increased mass requires more energy to move, resulting in higher fuel consumption. The significance of this relationship highlights the potential benefits of weight reduction strategies in vehicle manufacturing, such as using lighter materials or innovative structural designs to enhance fuel efficiency without compromising safety and performance.

Figure 4(c) explores the relationship between engine torque and fuel consumption. The regression analysis yields a weak positive correlation, with the equation Y=0.0044174 X+10.1964 (X: Engine

Torque (Nm), Y: Fuel Consumption (km/l)) This weak correlation suggests that while there is some increase in fuel consumption with higher torque, the impact is minimal compared to engine capacity and vehicle weight. This insight implies that other factors, such as engine efficiency and transmission systems, may play a more crucial role in determining fuel consumption related to torque. Consequently, this finding emphasizes the need for a holistic approach to vehicle design, considering multiple factors to achieve optimal fuel efficiency.

These analyses highlight the complex interplay between engine capacity, vehicle weight, and torque in influencing fuel consumption. Understanding these relationships is essential for designing more fuel-efficient SUVs. Future research should incorporate additional variables and advanced modeling techniques to elucidate

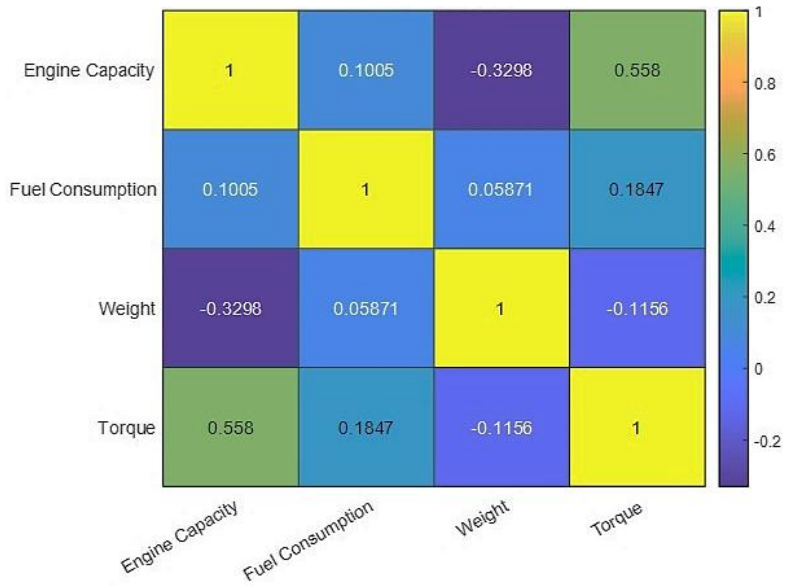


Figure 5. The correlation between the variables studied, namely engine capacity, fuel consumption, vehicle weight and torque

Figure 5 presents the correlation matrix between the key variables studied: engine capacity, fuel consumption, vehicle weight, and torque. The Pearson correlation coefficient, denoted as r, ranges from -1 to 1. An r value of -1 indicates a perfect negative linear relationship, 0 indicates no linear relationship, and 1 indicates a perfect positive linear relationship. The Pearson correlation coefficient was calculated using the following formula [24], [25]:

$$r = \frac{\sum(X_i - \bar{X})(Y_i - \bar{Y})}{\sqrt{\sum(X_i - X)^2 \sum(Y_i - Y)^2}} \tag{1}$$

Where X_i and Y_i are individual data points, and $\bar{X}$ and $\bar{Y}$ are the means of the variables X and Y, respectively. The sign of r indicates the direction of the relationship (positive or negative), while the magnitude indicates its strength.

In this study, we followed the guidelines provided by Dancey and Reidy [26] to interpret the strength of the Pearson correlation coefficients:

- Very weak correlation: 0 to ±0.19
- Weak correlation: ±0.20 to ±0.39
- Moderate correlation: ±0.40 to ±0.59
- Strong correlation: ±0.60 to ±0.79
- Very strong correlation: ±0.80 and above

The matrix values indicate the strength and direction of the relationships between these variables. It shows that engine capacity and torque have a moderately strong positive correlation (0.558), which is expected to be larger engines typically produce more torque. However, the correlation between engine capacity and fuel consumption is weak (0.1005), suggesting that engine size alone does not significantly predict fuel consumption, indicating that other factors, such as aerodynamics or engine efficiency, might play a larger role. Similarly, the correlation between vehicle weight and fuel consumption is very weak (0.05871), which is somewhat surprising given that heavier vehicles consume more fuel. This could imply that external factors like driving conditions or vehicle technology overshadow the expected weight impact in this dataset. Additionally, the correlation between torque and fuel consumption is weak (0.1847), further suggesting that factors beyond engine power, such as transmission efficiency and aerodynamics, are likely to be more influential in determining fuel efficiency. Another interesting observation is the negative correlation between vehicle weight and engine capacity (-0.3298), implying that vehicles with larger engines tend to be somewhat lighter in this dataset. This may reflect specific design choices aimed at balancing performance with weight optimization. Overall, while the matrix shows some relationships, the generally weak correlations highlight the complexity of fuel consumption, which is influenced by many factors beyond just engine capacity, weight, and torque, underscoring the need for further research to include additional variables and a more comprehensive approach to understanding fuel efficiency.

Our findings are consistent with several previous studies that indicate vehicle weight is one of the dominant factors influencing fuel consumption. For example, Cheah et al. demonstrated that increasing vehicle weight significantly raises fuel consumption [27]. This aligns with the general theory of energy efficiency, which posits that heavier vehicles require more energy to move, leading to higher fuel consumption. The study by Lewander et al. further supports this theory by showing that vehicle weight directly impacts fuel performance through the mechanism of torque control in the engine [16]. However, the findings reveal a weak correlation between engine capacity and fuel consumption (correlation coefficient: 0.1005), contrasting with other studies that reported a stronger positive correlation between engine capacity and fuel consumption, typically finding that larger engines consume more fuel due to increased power output. One possible explanation for this discrepancy is using advanced engine technologies in modern diesel SUVs in the Indonesian market. Technologies such as i-VTEC and Variable Timing Control (VTC) [15]–[17] are designed to optimize engine performance and improve fuel efficiency, even in vehicles with larger engine capacities. These technologies likely reduce the fuel consumption typically associated with larger engines, explaining the weaker correlation observed in our dataset.

This study also found a weak correlation between torque and fuel consumption (correlation coefficient: 0.1847). This finding is consistent with studies by Salafuddin et al., which also demonstrated that engine torque alone is not a strong predictor of fuel consumption [28]. Previous research suggests that other factors, such as aerodynamics, transmission efficiency, and engine management systems, are more crucial in determining overall fuel efficiency [Author et al., Year]. This aligns with our observation that factors beyond torque, such as transmission systems and driving conditions, play a more significant role in fuel consumption.

4. Conclusions

This study presents a detailed analysis of fuel consumption in diesel SUVs in the Indonesian market, focusing on the relationships between engine capacity, vehicle weight, and engine torque. Our analysis revealed a moderate positive correlation between vehicle weight and fuel consumption, affirming that weight is a significant factor influencing fuel efficiency. However, a weak correlation between engine capacity and fuel consumption was observed, suggesting that modern engine technologies, such as i-VTEC and Variable Timing Control (VTC), may reduce the impact of larger engines on fuel consumption. This finding contrasts with some earlier studies that reported stronger correlations, indicating that advances in engine design are helping mitigate traditional fuel consumption patterns associated with larger engines. Moreover, the correlation between engine torque and fuel consumption was weak, further supporting the idea that other factors—such as aerodynamics, transmission systems, and driving conditions—play a more substantial role in determining fuel efficiency. This study contributes to the growing body of research suggesting that, while traditional factors like vehicle weight remain important, modern technological advancements are reshaping the relationship between engine specifications and fuel consumption in diesel SUVs. Future research should explore the impact of these technologies in greater detail, particularly in different market segments and driving conditions.

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