

# DOKUMEN BUKTI SIMILARITY CHECK JURNAL INTERNASIONAL SCOPUS Q2 SEBAGAI PENULIS PERTAMA DAN KORESPONDENSI

**Judul Artikel:** Modeling Fuel Consumption of Heavy-duty Trucks Using Telematics Data

**Jurnal:** Periodica Polytechnica Transportation Engineering (Scopus Q2, ISSN: [1587-3811](#))

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Dokumen ini disusun sebagai bukti pendukung kelengkapan artikel ilmiah berjudul "Modeling Fuel Consumption of Heavy-Duty Trucks Using Telematics Data" yang diajukan dan diproses pada jurnal Periodica Polytechnica Transportation Engineering. Dokumen ini memuat bukti pemeriksaan orisinalitas naskah awal, identitas artikel, serta hasil similarity report yang menunjukkan tingkat kemiripan sebesar 8% berdasarkan laporan yang dibuat pada 17 September 2024. Bukti ini digunakan untuk mendukung bahwa naskah telah melalui tahapan pemeriksaan awal sebelum proses review, revisi, acceptance, dan publikasi akhir.

# Pradana

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**Submission date:** 17-Sep-2024 12:59AM (UTC-0500)

**Submission ID:** 2438313546

**File name:** Journal\_PPTR\_PWN.docx (719.16K)

**Word count:** 4673

**Character count:** 29150

# Modeling Fuel Consumption of Heavy-Duty Trucks Using Telematics Data

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## Abstract

Road transport, particularly heavy-duty trucks, is a significant contributor to CO<sub>2</sub> and NO<sub>x</sub> emissions, especially in developing nations such as Indonesia. This research introduces a novel fuel consumption model for trucks compliant with Euro-3 and Euro-4 emission standards, leveraging real-time telematics data to enhance fuel efficiency and mitigate emissions. The two main approaches are multiple linear regression with Box-Cox transformation and Generalized Linear Models (GLM), with independent variables including average operation speed, gross vehicle weight, and road gradient, collected from major logistics corridors in Indonesia. Empirical results indicate that the Box-Cox transformation model outperforms the GLM, exhibiting lower deviance and Root Mean Square Error (RMSE). The analysis reveals that average operation speed and truck type positively influence fuel consumption, while gross weight and road gradient negatively impact it. Euro-4 trucks demonstrate higher fuel efficiency and lower emissions compared to Euro-3 trucks, though further refinement of the predictive model for Euro-4 trucks is warranted. This study underscores the critical role of enhancing fuel efficiency in reducing emissions, with Euro-4 technology not only boosting efficiency but also substantially cutting greenhouse gas emissions. Moreover, the integration of telematics technology facilitates precise data acquisition, fostering energy optimization and emission reduction initiatives within the transportation sector. Future research should explore the integration of machine learning techniques to capture more complex patterns and extend model applicability across diverse operating conditions, particularly within the context of developing countries.

## Keywords

fuel consumption model, emission reduction, euro-4 truck, telematics data, heavy-duty truck

## 1 Introduction

The transportation sector, particularly the trucking industry, is a significant contributor to global CO<sub>2</sub> emissions, accounting for approximately 25% of total emissions within the sector (Al-Hasan, 2007). In Indonesia, freight trucks represent a notable source of air pollution, contributing to both local air quality degradation and climate change. Heavy-duty trucks are responsible for approximately 25% of CO<sub>2</sub> emissions from road transportation and 5% of total GHG emissions within the European Union (Yang et al., 2021; White et al., 2017). These vehicles also emit higher levels of CO<sub>2</sub> and NO<sub>x</sub> compared to light trucks (Mahalana et al., 2022). In Indonesia, the trucking industry faces high operational costs, where fuel alone represents approximately 28% of total operating expenses (Brasukra and Hergesell, 2008).

The practice of overloading, although often employed to increase short-term profits, negatively impacts fuel efficiency and increases emissions (Jacob and Pell-de La Beaumelle, 2010; Titi et al., 2018). Countries such as the United States and China have adopted aerodynamic-

enhancement technologies, heat recovery systems, and low-rolling resistance tires to reduce fuel consumption in heavy-duty trucks (White et al., 2017). In response to global climate agreements, such as the Paris Agreement and Sustainable Development Goals, the Indonesian government has introduced Euro-4 emission standards with the aim of reducing emissions and improving fuel efficiency (Ministry of Environment and Forestry, 2017). Euro-4 standards are reported to offer 10-15% improvements in fuel efficiency compared to Euro-3 trucks, with CO<sub>2</sub> and NO<sub>x</sub> emissions reduced by up to 30% (Erkkilä and Nylund, 2007; Maulidya, 2019). This improvement not only enhances environmental sustainability but also significantly reduces operating costs for the trucking industry, which is critically important given the high operational costs.

Despite the potential benefits offered by Euro-4 technology, there remains a lack of studies directly comparing the fuel consumption of Euro-4 and Euro-3 trucks under actual operational conditions within the Indonesian context. Previous studies have frequently relied on the HDM-4 model, which often requires recalibration to

align with local conditions (Zaabar and Chatti, 2010). However, the accuracy of such calibrations is limited in the absence of relevant local data, resulting in significant errors in fuel consumption predictions for heavy-duty trucks (Greenwood et al., 2007). This research addresses this gap by integrating manufacturer-authorized telematics technology, enabling real-time data collection without the need for complex and expensive field experiments (Perrotta et al., 2019).

Unlike traditional methodologies that rely on manual calibration and rigid assumptions, the use of telematics data allows for the comprehensive capture of key variables such as average operation speed, vehicle gross weight, and road gradient, all of which are critical determinants of fuel consumption (Wang et al., 2017; Posada-Henao, 2023). Building on the work of Iskandar (2000), who developed a fuel consumption model for Euro-1 trucks, this study employs Euro-4 standards and telematics technology, representing a novel and underexplored approach in Indonesia.

The research focuses on 5-axle trucks, the most common type of heavy-duty vehicle in Indonesia, which enhances the representativeness of the findings in actual operational contexts. It is expected that this approach will produce a more accurate fuel consumption model, which will not only contribute to scientific knowledge but also inform policies related to fuel efficiency and GHG emission reduction in Indonesia. The research outcomes are anticipated to have significant implications, offering a more accurate model of fuel consumption and presenting the potential of Euro-4 technology to improve fuel efficiency by up to 15%, thus contributing to both emissions reductions and operational cost savings (Erkkilä and Nylund, 2007; Brasukra and Hergesell, 2008; Maulidya, 2019).

## 2 Methodology

This study focuses on containerized semi-trailer trucks with Euro-3 and Euro-4 emission standards operating on the Tanjung Priok Port - Bandung route, one of the major logistics corridors in Indonesia. The selection of Hino FG 260 TH (Euro-4) and UD Qvester GKE (Euro-3) trucks was based on the results of an initial survey. Both trucks feature a fully integrated telematics system and exhibit similar weight-to-power ratios of 5.6 kW/ton and 5.7 kW/ton, respectively, ensuring uniformity in truck performance (Mahalana et al., 2022; Environmental Agency of DKI Provincial Government, 2019).

Data were collected over two months (February and March 2024) through a manufacturer-authorized telematics system, which integrates GPS, Hino Connect, My UD Fleet, and a Transport Management System (TMS) to capture real-time information on speed, gross vehicle weight, fuel consumption, and road gradient. Telematics data refers to information collected from vehicle sensor systems, including GPS, On-Board Diagnostic (OBD-II), and Mobile Network IoT systems. This data encompasses critical vehicle performance metrics such as speed, location, fuel consumption, and operational efficiency, which are transferred via the Electronic Control Unit (ECU) or IoT mobile network (Farzaneh et al., 2020; SAE International, 2022; Perrotta et al., 2019).

Road gradient was derived using Google Earth elevation data, providing sufficient accuracy for transportation applications, with a Mean Absolute Error (MAE) of approximately 1.32 meters and a Root Mean Square Error (RMSE) of 2.27 meters (Wang et al., 2017). The data collection was conducted under controlled, distraction-free conditions with consistent average speeds and road conditions (Zhang et al., 2019). Data pre-processing included outlier removal via the Z-score method (using a threshold of  $\pm 3$  standard deviations) and linear interpolation to address missing data and maintain dataset integrity.

Two models were employed for analysis: Model 1 utilized Ordinary Least Squares (OLS) regression to model the relationship between speed, gross vehicle weight, and road gradient on fuel consumption. Assumptions of linear regression, such as residual normality and homoscedasticity, were tested; where violations occurred, corrections were made using robust standard errors and the Box-Cox transformation (King and Roberts, 2014; Malik et al., 2018). Alternatively, Model 2 applied Generalized Linear Models (GLM) with a Gamma distribution and log links to address skewness in fuel consumption data, providing a robust solution for heteroscedasticity issues (Dobson and Barnett, 2018).

Model validation was conducted using the Akaike Information Criterion (AIC) and Bayesian Information Criterion (BIC) to identify the optimal model, both of which offer advantages over the traditional  $R^2$  statistic for model selection (Dobson and Barnett, 2018). To ensure model reliability, predicted values were compared with observed fuel consumption data, and a null hypothesis test was performed to assess whether the differences were statistically significant. The Wilcoxon Signed-Rank test, a nonparametric method that does not rely on normality

assumptions, was utilized to test the similarity between paired observations. The null hypothesis ( $H_0$ ) posited no significant difference between predicted and observed fuel consumption, implying that the discrepancy between the two would be zero (Deshpande et al., 2017). By rejecting or accepting the null hypothesis, the accuracy of the model in capturing real-world fuel consumption data can be rigorously evaluated (Deshpande et al., 2017).

### 3 Data and Result

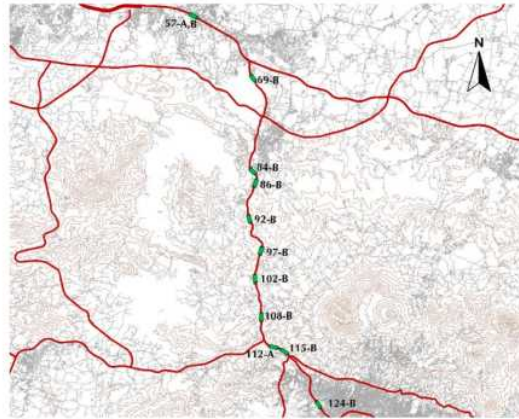
Section 3 provides a detailed analysis of the data processing and modeling steps undertaken in this research. Section 3.1 elaborates on the data management procedures, including segmentation, clustering, and outlier detection, within the context of truck fuel consumption modeling. The process ensures that the dataset is clean and suitable for further analysis. Section 3.2 presents a comprehensive examination of the factors influencing fuel consumption, followed by the development of a fuel consumption model specifically designed for Euro-3 and Euro-4 emission standard trucks. Lastly, Section 3.3 evaluates the accuracy and predictive performance of the proposed truck fuel consumption model. Various validation metrics, such as the Akaike Information Criterion (AIC) and Bayesian Information Criterion (BIC), are employed to assess the model's robustness and alignment with observed data.

#### 3.1 Data Processing

Data management in this study begins with the segmentation of road sections based on road gradient and vehicle speed under non-congested or free-flow conditions. This segmentation is intended to yield more homogeneous and representative observation segments, facilitating a more accurate analysis of the impact of road gradient on vehicle performance and fuel consumption. The study classifies road gradients into three categories: flat, hilly, and mountainous terrains, which were identified from 12 road segments on the Jakarta-Cikampek, Cipularang, and Purbaleunyi Toll Roads. The flat terrain segments include segments 57-A and 57-B, with maximum gradients of 0.01% and 0.07%, respectively. The hilly and mountainous segments include segment 108-A, with a gradient of 4.72%, and segment 92-B, with a gradient of 6.13%. The specific details of the gradients in each observation segment are provided in Table 1. A total of 1,094 speed observations were collected during February and March 2024, comprising 474 data points for Euro-4 trucks and 620 data points for Euro-3 trucks. These data were categorized based

on vehicle speed, gross vehicle weight, and road gradient. Speed was divided into three categories: low (below 20 km/h), medium (20-40 km/h), and high (above 40 km/h). Gross vehicle weight (load factor) was classified into three categories: low (below 30%), medium (30-75%), and high (more than 75%). Road gradient was categorized as flat (maximum 4%), hilly (maximum 5%), and mountainous (maximum 6%).

Fig. 1 The road sections classified based on road gradient



The results, as shown in Table 1, indicate significant variations in speed between Euro-4 and Euro-3 trucks. The highest recorded speed was observed on segment 57-A for Euro-4 trucks, with an average of 46.88 km/h (standard deviation 7.78 km/h). In comparison, Euro-3 trucks recorded an average of 42.92 km/h (standard deviation 6.36 km/h). The lowest speed for Euro-4 trucks was recorded on segment 92-B, averaging 31.01 km/h (standard deviation 8.85 km/h), whereas Euro-3 trucks recorded an average of 26.59 km/h (standard deviation 8.71 km/h). These findings demonstrate that Euro-4 trucks generally operate at higher speeds than Euro-3 trucks, particularly on segments with flat and hilly gradients.

Significant differences were also observed in terms of gross vehicle weight. On segment 92-B, Euro-3 trucks recorded the highest gross vehicle weight, averaging 33.04 tons (standard deviation 1.035 tons), while Euro-4 trucks had an average weight of 28.33 tons (standard deviation 0.901 tons). Conversely, the lowest gross weight for Euro-4 trucks was recorded on segment 124-B, averaging 23.87 tons (standard deviation 0.736 tons). In contrast, Euro-3 trucks recorded their lowest gross weight on segment 57-B, with an average of 30.78 tons (standard deviation 1.072 tons). This difference suggests that Euro-4 trucks are more

frequently operated with lighter loads compared to Euro-3 trucks, which likely contributes to their superior fuel efficiency.

Regarding fuel consumption, Euro-4 trucks exhibited significantly higher efficiency on segment 57-B, recording an average consumption of 6.98 km/l (standard deviation 2.86), while Euro-3 trucks recorded 3.76 km/l (standard deviation 1.25). In steeper gradient segments, such as segment 92-B, fuel consumption decreased for both truck types. However, Euro-4 trucks maintained better efficiency, with an average consumption of 0.69 km/l (standard deviation 0.27), compared to Euro-3 trucks, which consumed 0.61 km/l (standard deviation 0.29). The higher load of Euro-3 trucks likely contributed to their lower efficiency, while Euro-4 trucks exhibited greater resilience in maintaining performance under steeper gradient conditions.

3.2 Fuel consumption modeling

This study models fuel consumption (FC) as the dependent variable, with independent variables including average operating speed (V), gross vehicle weight (W), positive road gradient (G), and truck type as a dummy variable (T). Average operating speed refers to the mean speed of a vehicle over a specified period, influenced by traffic conditions, road gradients, and interactions between vehicles, where gradient resistance reduces speed on uphill roads (Odoki and Kerali, 2006). Gross vehicle weight encompasses the total weight of the vehicle, including the cargo, truck crew, components, and vehicle equipment, which in heavy cargo trucks typically exceeds 11,794 kg (Bennett, 2020). Initial simple linear regression analysis revealed that V exhibited a significant non-linear relationship with fuel consumption, with an R<sup>2</sup> of 0.509 and an F-statistic of 856.769. W showed a non-linear logistic and exponential relationship, with an R<sup>2</sup> of 0.349 and an F-statistic of 442.222. S also had a significant influence, with an R<sup>2</sup> of 0.356 and an F-statistic of 228.128. Given the statistical significance of all variables, the analysis proceeded with multiple linear regression.

Table 1 Summary of speed, gross weight, and fuel consumption data by road gradient

Segment	Road Gradient (%)	Truck Type	Data count	Average operation speed (V)		Gross vehicle Weight (W)		Fuel consumption (FC)	
				Mean V (km/jam)	Standard Deviation	Mean W (ton)	Standard Deviation	Mean FC (km/l)	Standard Deviation
57-A	0.01	Euro-4	44	46.88	7.78	32.09	5.57	5.38	1.41
		Euro-3	54	42.92	6.36	32.67	7.48	3.16	0.77
57-B	0.07	Euro-4	37	47.16	8.73	28.42	8.72	6.98	2.86
		Euro-3	51	46.42	7.81	30.78	10.72	3.76	1.25
69-B	1.00	Euro-4	37	46.44	7.50	26.58	9.01	6.88	2.96
		Euro-3	52	46.05	6.26	30.04	10.67	3.58	1.14
84-B	4.32	Euro-4	44	41.07	9.97	27.62	9.79	3.12	1.32
		Euro-3	54	34.63	9.85	31.18	11.16	1.99	0.88
86-B	5.24	Euro-4	47	39.82	10.03	27.51	9.63	1.97	0.87
		Euro-3	53	31.36	11.22	31.23	11.33	1.36	0.63
92-B	6.13	Euro-4	39	31.01	8.85	28.33	9.01	0.69	0.27
		Euro-3	59	26.59	8.71	33.04	10.35	0.61	0.29
97-B	4.41	Euro-4	44	35.96	10.04	29.79	10.01	2.69	1.23
		Euro-3	51	33.29	9.84	31.12	10.82	1.84	0.85
102-B	2.76	Euro-4	39	38.54	10.68	26.81	8.84	4.32	1.71
		Euro-3	50	35.54	12.35	31.52	10.61	2.19	1.02
108-A	4.72	Euro-4	42	28.63	9.26	30.81	5.96	1.80	0.48
		Euro-3	52	26.43	7.53	33.02	7.12	1.21	0.43
112-B	2.85	Euro-4	38	41.79	9.48	30.02	9.08	3.59	1.47
		Euro-3	55	38.98	10.49	32.14	10.53	2.48	0.99
115-B	3.68	Euro-4	34	43.56	8.69	28.35	9.22	3.09	1.25
		Euro-3	50	39.65	9.65	31.88	10.20	2.01	0.74

124-B	3.37	Euro-4	31	45.53	6.82	23.87	7.36	3.93	1.14
		Euro-3	39	40.13	8.90	30.64	9.98	2.24	0.84

At the next stage, Model 1 was analyzed using multiple linear regression with the application of a Box-Cox transformation ( $\lambda = 0.25$ ) to address issues of non-normal residual distributions. Following the transformation, the Kolmogorov-Smirnov test yielded a p-value of 0.095, indicating that the residuals approached a normal distribution. Multicollinearity tests revealed Variance Inflation Factor (VIF) values ranging from 1.0313 to 1.578, confirming the absence of multicollinearity. Additionally, the Durbin-Watson test produced a value of 1.953, close to the ideal value of 2, suggesting no significant autocorrelation. While the Glejser test identified heteroscedasticity in the W and T variables, the Breusch-Pagan test ( $p = 0.165$ ) indicated that residual variance was constant.

The multiple linear regression results for Model 1 demonstrate that all independent variables have a statistically significant impact on fuel consumption. Average operating speed (V) is positively correlated with fuel consumption, with increased speeds resulting in higher fuel consumption. Conversely, gross vehicle weight (W) and positive road gradient (G) exhibit a negative correlation, where increases in weight or gradient are associated with decreased fuel consumption. Additionally, Euro-4 trucks were found to be more fuel-efficient than Euro-3 trucks, as evidenced by the significant coefficient on the truck type dummy variable, indicating the superior fuel efficiency of Euro-4 trucks. Table 2 presents the coefficients, t-values, and p-values for each variable, confirming that all variables are statistically significant at the 5% significance level, with the critical t-value being 1.647.

Table 2 Model 1 parameter estimation

Parameter	Coefficient	Robust Standard Error	t-value	p-value
Intercept	1.539	0.009	178.989	<0.001
V2	6.64E-02	2.33E-03	28.542	<0.001
W	-0.009	0.000	-66.986	<0.001
G	-0.048	0.001	-54.371	<0.001
T	0.098	0.003	35.953	<0.001

As an alternative approach, Model 2 employs Generalized Linear Models (GLM) with a Gamma distribution and log links to model the relationship between the same set of variables. The Goodness of Fit test indicated a strong fit for the model, with a deviance of 8.827 and a

deviance/df ratio of 0.011. In contrast, the Pearson Chi-Square test yielded a value of 8.755 with a Pearson Chi-Square/df ratio of 0.011, further confirming the model's adequacy.

The results of the GLM parameter estimation indicate that both average operating speed (V) and truck type (T) exhibit a statistically significant positive effect on fuel consumption, as demonstrated by their respective coefficients of 0.018 and 0.316. Conversely, gross vehicle weight (W) and positive road gradient (G) are found to have a statistically significant negative influence on fuel consumption, with coefficients of -0.030 and -0.148, respectively. The complete parameter estimation results, including detailed coefficient values, can be found in Table 3.

Table 3 Model 2 parameter estimation

Parameter	Coefficient	Robust Standard Error	Wald Chi-Square Value	p-value
Intercept	1.399	0.0360	1,507.653	<0.001
V	0.018	0.0006	1,025.472	<0.001
W	-0.030	0.0004	4,435.602	<0.001
G	-0.148	0.0025	3,433.817	<0.001
T	0.316	0.0082	1,465.779	<0.001

A comparative analysis between Model 1 and Model 2 demonstrates that Model 1 outperforms Model 2 in terms of predictive accuracy and model fit. Model 1 exhibits a lower deviance value of 0.947 compared to 8.827 for Model 2, as well as smaller Root Mean Squared Errors (RMSEs) of 0.033 and 0.296, respectively. Furthermore, the adjusted R-squared value of 0.85 suggests that the independent variables in this model explain 85.8% of the variability in fuel consumption. The Akaike Information Criterion (AIC) for Model 1 is -3,246.625, which is substantially lower than that of Model 2, indicating a reduced prediction error and superior model performance.

Based on the comparative analysis of performance metrics shown in Table 3, the multiple linear regression model with Box-Cox transformation is recommended as the best model for predicting fuel consumption in Euro-3 and Euro-4 trucks, as it offers greater accuracy and a better ability to explain the variability in fuel consumption. The final regression equation derived from Model 1 is:

$$FC^{0,25} = 1,539 + 0,000066V^2 - 0,009W - 0,048G + 0,098T \quad (1)$$

where:

FC = Fuel consumption (km/l)

V = Average operating speed (km/jam)

W = Gross vehicle weight (ton)

G = Positive road gradient (%)

T = Truck type (Euro-4=1 dan Euro-3=0)

**Table 4** Comparison of model performance metrics

Indicator	Model 1	Model 2
Deviance	0.947	8.827
Pearson Chi-Square	0.947	8.755
Log Likelihood	1,629.313	7.241
AIC	-3,246.625	-2.483
AICC	-3,246.523	-2.380
BIC	-3,218.311	25.832
CAIC	-3,212.311	31.832
RMSE	0.033	0.296
MAE	0.027	0.217
RSS	0.947	72.810

**3.3 Comparison of modeled predictions and observed outcomes**

Based on the Wilcoxon Signed Ranks Test, a comparison was made between observed and predicted fuel consumption for Euro-4 and Euro-3 trucks to evaluate the accuracy of the predictive model. Regarding Euro-4 trucks, the Z value is -1.700, and the Asymptotic Significance (2-tailed) value of 0.089 indicates that the p-value is greater than 0.05, implying no statistically significant difference between the observed and predicted fuel consumption. These findings suggest that while the model's predictions are generally close to the observations, there are slight discrepancies that may become relevant in operational contexts, potentially due to factors such as terrain variation or other external conditions.

In the case of Euro-3 trucks, the Z value was calculated as -0.072, and the Asymptotic Significance (2-tailed) value of 0.943 indicates that the difference between observed and predicted values is minimal, with a p-value much greater than 0.05. These numbers demonstrate that the predictive model for Euro-3 trucks more accurately reflects actual fuel

consumption, offering a higher level of confidence in its reliability for predicting field performance.

Overall, for both Euro-4 and Euro-3 trucks, there were no significant differences between the predicted and observed results, with the Euro-3 model showing a higher level of accuracy. These findings support the validity of the predictive model used in this study, particularly for real-world applications. These results align with previous research, which has demonstrated that predictive models based on telematics data can reduce prediction errors for trucks with lower emission standards. However, the small discrepancies observed in Euro-4 trucks could be the focus of future research, particularly by considering additional variables such as road surface conditions to improve model accuracy further.

**4 Conclusion**

This study has successfully developed a telematics data-based truck fuel consumption model using two primary approaches: multiple linear regression with Box-Cox transformation and Generalized Linear Models (GLM). The results demonstrate that the model incorporating Box-Cox transformation is superior in terms of deviance, RMSE, and AIC compared to the GLM model, with operating speed, vehicle gross weight, road grade, and truck type identified as significant factors influencing fuel consumption. The predictive model for Euro-3 trucks exhibited a high level of accuracy, while the model for Euro-4 trucks requires further refinement. This study also underscores the critical role of energy efficiency in the trucking industry in developing countries, particularly through the utilization of real-time telematics technology to promote fuel savings in Euro-4 standard trucks.

Despite these positive outcomes, this study has several limitations, including its geographical focus, which was restricted to specific routes in Indonesia, and the fact that it only considered Euro-3 and Euro-4 emission standards. Moreover, the reliance on manufacturer-authorized telematics data may limit the model's applicability in sectors where such technologies are not yet widely implemented. Additionally, factors such as weather conditions, traffic, and driver behavior were not incorporated into the model, which may affect its predictive accuracy under more complex operational conditions.

For future research, the application of machine learning could offer a more advanced approach to fuel consumption modeling, especially in capturing complex patterns and providing more accurate predictions across varying

operating conditions. Expanding the geographical scope and testing the model under different road and infrastructure conditions are also necessary to enhance the model's validity. Moreover, developing models for trucks with higher emission standards, such as Euro-5 and Euro-6, is crucial to support global emission reduction and energy efficiency improvement targets. Future research should also consider integrating additional variables, such as weather conditions and drivers' behavior while investigating the long-term impact of telematics and machine learning technologies on operational cost savings and energy efficiency. Finally, the adaptation of these technologies for small-scale transportation companies in developing countries represents an important avenue for exploration to ensure broader and more sustainable adoption.

## References

- Al-Hasan, M. (2007) "Evaluation of Fuel Consumption and Exhaust Emissions During Engine Warm-Up", *American Journal of Applied Sciences*, 4 (3), pp. 106–111. <https://doi.org/10.3844/ajassp.2007.106.111>
- Bennett, S. (2020) "Heavy Duty Truck Systems", 7th ed, [e-book] Cengage Learning, Inc. Boston, US. ISBN: 978-1305073623 Available at: <https://www.cengage.com/e/heavy-duty-truck-systems-44-7th-edition-7e-bennett/9781337787109> [Accessed: 23 June 2023].
- Brasukra, S., Hergesel, A. (2008) "Biaya Transportasi Barang Angkutan, Regulasi, Dan Pungutan Jalan Di Indonesia", Asia Foundation, Jakarta. ISBN 978-979-16123-5-7 [online] Available at: [https://supplychainindonesia.com/wp-content/files/Biaya\\_Transportasi\\_Barang\\_Asia\\_Foundation\\_tanpa\\_peta\\_LAIN\\_LAIN.pdf](https://supplychainindonesia.com/wp-content/files/Biaya_Transportasi_Barang_Asia_Foundation_tanpa_peta_LAIN_LAIN.pdf) [Accessed: 4 June 2023] (in Indonesian)
- Deshpande, J. V., Naik-Nimbalkar, U., Dewan, I. (2017) "Nonparametric Statistics: Theory and Methods", World Scientific, New Jersey, US. ISBN 9789814663571
- Environmental Agency of DKI Provincial Government. (2019) "Penyusunan Indeks Kualitas Lingkungan Hidup DKI Jakarta Tahun 2019", [pdf] DKI Provincial Government, Indonesia. Available at: <https://lingkunganhidup.jakarta.go.id/files/kajian/2019/IKLH-2019/Laporan-IKLH-2019.pdf> [Accessed: 10 June 2023] (in Indonesian)
- Dobson, A. J. and Barnett, A. G. (2018) "An Introduction to Generalized Linear Models Fourth Edition", [e-book] CRC Press, New York, US. ISBN: 9781315182780 <https://doi.org/10.1201/9781315182780>
- Erkkilä, K. and Nylund, N.-O. (2007) "Fuel Efficiency Of New European HD Vehicles", DEER 2007 Conference, Detroit, US, Aug. 12–16. [online] Available at: <https://www.energy.gov/eere/vehicles/articles/fuel-efficiency-new-european-hd-vehicles> [Accessed: 10 March 2023]
- Farzaneh, R., Johnson, J., Jaikumar, R., Ramani, T., Zietsman, J. (2020) "Use of Vehicle Telematics Data to Characterize Drayage Heavy-Duty Truck Idling", *Transportation Research Record*, 2674 (11), pp. 542–553. <https://doi.org/10.1177/0361198120945990>
- Greenwood, I. D., Dunn, R. C. M., Raine, R. R. (2007) "Estimating the Effects of Traffic Congestion on Fuel Consumption and Vehicle Emissions Based on Acceleration Noise", *Journal of Transportation Engineering*, 133 (2), pp. 96–104. [https://doi.org/10.1061/\(ASCE\)0733-947X\(2007\)133:2\(96\)](https://doi.org/10.1061/(ASCE)0733-947X(2007)133:2(96))
- Iskandar, H., Idris, M., Sukwanti, T. K. (2000) "Pengkajian Pemakaian Bahan Bakar Kendaraan Di Perkotaan", [pdf] Ministry of Public Works and Housing, Bandung, Indonesia. Available at: <https://simantu.pu.go.id/personal/img-post/autocover/d20334447c76c5ebace4129764ea3639.pdf> [Accessed 18 February 2023] (in Indonesian)
- Jacob, B. and Feypell-de La Beaumelle, V. (2010) "Improving Truck Safety: Potential of Weigh-in-Motion Technology", *IATSS Research*, 34 (1), pp. 9–15. <https://doi.org/10.1016/j.iatssr.2010.06.003>
- Ministry of Environment and Forestry of the Republic of Indonesia. (2017) "Peraturan Menteri Lingkungan Hidup Dan Kehutanan Nomor P.20/Menlhk/Setjen/Kum.1/3/2017 Tentang Mutu Emisi Gas Buang Bermotor Tipe Baru Kategori M, Kategori N, Dan Kategori O", [pdf] Republic of Indonesia, Jakarta, Indonesia. Available at: <https://ppkl.menlhk.go.id/website/filebox/653/190930092022Peraturan%20Menteri%20LHK%20Nomor%20P%2020%20Tentang%20Baku%20Mutu%20Emisi%20Gas%20Buang%20Kendaraan%20Bermotor%20Tipe%20Baru%20Kategori%20M%20Kategori%20N%20dan%20Kategori%20O.PDF> [Accessed 28 April 2023] (in Indonesian)
- King, G., Roberts, M. E. (2015) "How Robust Standard Errors Expose Methodological Problems They Do Not Fix, and What to Do about It", *Political Analysis*, 23 (2), pp. 159–179. <https://doi.org/10.1093/pan/mpu015>
- Mahalana, A., Yang, L., Dallmann, T., Lestari, P., Maulana, K., Kusuma, N. (2022) "Pengukuran Emisi Kendaraan Bermotor Real-World Di Jakarta, Indonesia", [pdf] International Council on Clean Transportation, London, UK. Available at: <https://theicct.org/wp-content/uploads/2022/11/true-jakarta-remote-sensing-in-nov22.pdf> [Accessed 18 May 2023] (in Indonesian)
- Malik, F., Khan, A., Tahir, M. S. A. (2018) "Box-Cox Transformation Approach For Data Normalization: A Study Of New Product Development In Manufacturing Sector Of Pakistan", *Journal of Business Studies-JBS*, 14 (1), pp. 110–119. <https://doi.org/10.46745/ilma.ibtjbs.2018.141.9>
- Maulidya, I. (2019) "Kesiapan Angkutan Jalan Dalam Menghadapi Penerapan Standar Emisi Euro 4", *Warta Penelitian Perhubungan*, 31 (1), pp. 1–14. (in Indonesian) <https://doi.org/10.25104/warlit.v31i1.913>
- Odoki, J. B., Kerali, H. G. R. (2006) "Analytical Framework and Model Descriptions. Highway Development and Management Series", 4, 2nd ed, World Road Association PIARC, Paris, France. ISBN: 2-84060-058-7
- Perrotta, F., Parry, T., Neves, L. C., Buckland, T., Benbow, E., Mesgarpour, M. (2019) "Verification of the HDM-4 Fuel Consumption Model Using a Big Data Approach: A UK Case Study", *Transportation Research Part D: Transport and Environment*, 67, pp. 109–118. <https://doi.org/10.1016/j.trd.2018.11.001>
- Posada-Henao, J. J., Sarmiento-Ordosgoitia, I., Correa-Espinal, A. A. (2023) "Effects of Road Slope and Vehicle Weight on Truck Fuel

- Consumption. Sustainability (Switzerland)", 15 (1), pp. 1–19.  
<https://doi.org/10.3390/su15010724>
- SAE International. (2022) "Vehicle Application Layer, SAE Standard J1939/71\_202208", SAE International Recommended Practice.  
[https://doi.org/10.4271/J1939/71\\_202208](https://doi.org/10.4271/J1939/71_202208)
- Titli, H. H., Coley, N. J., Latifi, V. (2018) "Evaluation of Pavement Performance Due to Overload Single-Trip Permit Truck Traffic in Wisconsin", *Advances in Civil Engineering*, 2018, pp. 1–11.  
<https://doi.org/10.1155/2018/1070653>
- Wang, J., Rakha, H. A., Fadhloun, K. (2017) "Validation of the Rakha-Pasumarthy-Adjerid Car-Following Model for Vehicle Fuel Consumption and Emission Estimation Applications", *Transportation Research Part D: Transport and Environment*, 55, pp. 246–261. <https://doi.org/10.1016/j.trd.2017.06.030>
- White, B., Kirsch, F., Levin, S., Skinner, I., Norris, J., Jones, L. (2017) "Analysis of Fuel Economy and GHG Emission Reduction Measures from Heavy Duty Vehicles in Other Countries and of Options For The EU" [pdf] The European Commission-DG Climate Action, London, UK. Available at: [https://climate.ec.europa.eu/document/download/6914f144-901d-4118-9097-94a24e549bac\\_en?filename=analysis\\_fuel\\_economy\\_hdv\\_en.pdf](https://climate.ec.europa.eu/document/download/6914f144-901d-4118-9097-94a24e549bac_en?filename=analysis_fuel_economy_hdv_en.pdf) [Accessed 14 April 2024].
- Yang, Z., Minjares, R., Kusumaningkatma, M., Sehleier, F., Herliana, L., Priatama, Y., Yani, A., Wahyudi, A., Simbolon, E., Ayu, D., Indah, D. (2021) "Truck Fleet Modernization in Indonesia Mitigation Action Outline", [pdf] Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ), Bonn, Germany. Available at: <https://changing-transport.org/publications/truck-fleet-modernization-in-indonesia/> [Accessed 18 May 2023].
- Zaabar, I., Chatti, K. (2010) "Calibration of HDM-4 Models for Estimating the Effect of Pavement Roughness on Fuel Consumption for U.S. Conditions", *Journal of the Transportation Research Board*, 2155, pp. 105–116. <https://doi.org/10.3141/2155-12>
- Zhang, X., Xu, J., Li, M., Li, Q., Yang, L. (2019) "Modeling Impacts of Highway Circular Curve Elements on Heavy-Duty Diesel Trucks' CO<sub>2</sub> Emissions", *International Journal of Environmental Research and Public Health*, 16 (14), 2514.  
<https://doi.org/10.3390/ijerph16142514>

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