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# IDENTIFICATION OF FACTORS AFFECTING FUEL CONSUMPTION OF AUTOMOBILES UNDER REAL OPERATING CONDITIONS AND DEVELOPMENT OF A METHOD FOR ITS REDUCTION

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**Abstract.** This article investigates the main factors affecting automobile fuel consumption under real operating conditions and develops approaches for reducing fuel consumption. The study evaluates the influence of vehicle speed, acceleration, braking, speed variability, and driving style on fuel consumption. Statistical and regression analyses were performed using parameters obtained under real driving conditions. Linear regression and Random Forest models were applied to predict fuel consumption. The results demonstrate that variations in vehicle speed and driving dynamics have a significant effect on fuel consumption. The Random Forest model demonstrated high predictive accuracy, achieving an $R^2$ value of 0.956 and an MSE of 0.003. The findings provide a basis for developing practical recommendations aimed at optimizing vehicle operation, reducing sudden acceleration and braking, and improving fuel efficiency under real operating conditions.

**Keywords:** automobile, fuel consumption, real operating conditions, vehicle speed, driving behavior, Random Forest.

## INTRODUCTION

Fuel consumption is one of the most important indicators characterizing the efficiency of automobile operation. Reducing fuel consumption is particularly important under real operating conditions, where the actual fuel consumption of vehicles is affected by a combination of traffic, road, vehicle, and driver-related factors. Unlike standardized laboratory conditions, real-world driving involves continuous changes in vehicle speed, acceleration, braking, traffic density, road conditions, and driving style. Therefore, determining the influence of these factors is essential for improving fuel efficiency.

Driving behavior has a significant effect on fuel consumption. Frequent acceleration and braking, sudden changes in speed, and unstable driving modes increase the energy required for vehicle movement and consequently lead to higher fuel consumption. In contrast, smooth and controlled driving with relatively stable speed can contribute to more efficient fuel use. In this regard, quantitative indicators characterizing speed variability, acceleration, deceleration, and driving dynamics can be used to evaluate the relationship between driving behavior and fuel consumption.

The complexity of real-world operating conditions makes it difficult to describe fuel consumption using only linear relationships. The influence of individual factors can vary depending on traffic conditions and the interaction between different driving parameters. Therefore, statistical analysis, regression methods, and machine-learning approaches provide opportunities to identify significant factors and improve the accuracy of fuel-consumption prediction.

The purpose of this study is to identify the main factors affecting automobile fuel consumption under real operating conditions and to develop an approach for reducing fuel consumption. Particular attention is given to vehicle speed variability, acceleration and braking characteristics, and driving style. In addition, linear regression and Random Forest models are used to evaluate the relationship

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between driving parameters and fuel consumption and to determine an effective method for predicting and reducing fuel consumption.

**RESEARCH METHODOLOGY**

The study was conducted to identify the main factors affecting automobile fuel consumption under real operating conditions and to develop an approach for reducing fuel consumption. Real-world driving parameters, including vehicle speed, acceleration, deceleration, speed variability, and driving style, were considered as the main explanatory factors. The analysis focused on quantitative indicators describing variations in vehicle movement and their relationship with fuel consumption.

To characterize driving behavior, statistical indicators such as standard deviation, coefficient of variation, mean absolute deviation, and quantile-based variation measures were used. Ten driving variability measures (VM1–VM10) were analyzed to determine their influence on fuel consumption. The relationships between these parameters and fuel consumption were evaluated using multivariate linear regression.

In addition, a Random Forest machine-learning model was applied to account for nonlinear relationships between driving parameters and fuel consumption. The performance of the models was evaluated using the coefficient of determination ($R^2$) and mean squared error (MSE). The obtained results were compared to determine the more accurate approach for predicting fuel consumption under real operating conditions.

Based on the identified significant factors and model results, recommendations were developed for reducing fuel consumption through smoother driving, maintaining a more stable vehicle speed, and minimizing unnecessary acceleration and braking.

**RESULTS**

The results of the study demonstrate that automobile fuel consumption under real operating conditions is strongly associated with vehicle speed, road conditions, traffic intensity, trip duration, and driving behavior. The analysis showed that low-speed operation, frequent stopping and restarting, sudden acceleration, and increased road gradient are among the main factors contributing to higher fuel consumption.

The analysis of vehicle speed showed that the fuel consumption gap reached 103.6±47.1% at an average speed of 10–20 km/h. In the 50–60 km/h range, this value decreased to 17.1±18.9%, representing one of the most favorable results. At speeds above 60 km/h, a slight increase in fuel consumption was observed. These results indicate that maintaining a relatively stable and appropriate speed is more efficient than operating the vehicle at very low or highly variable speeds.

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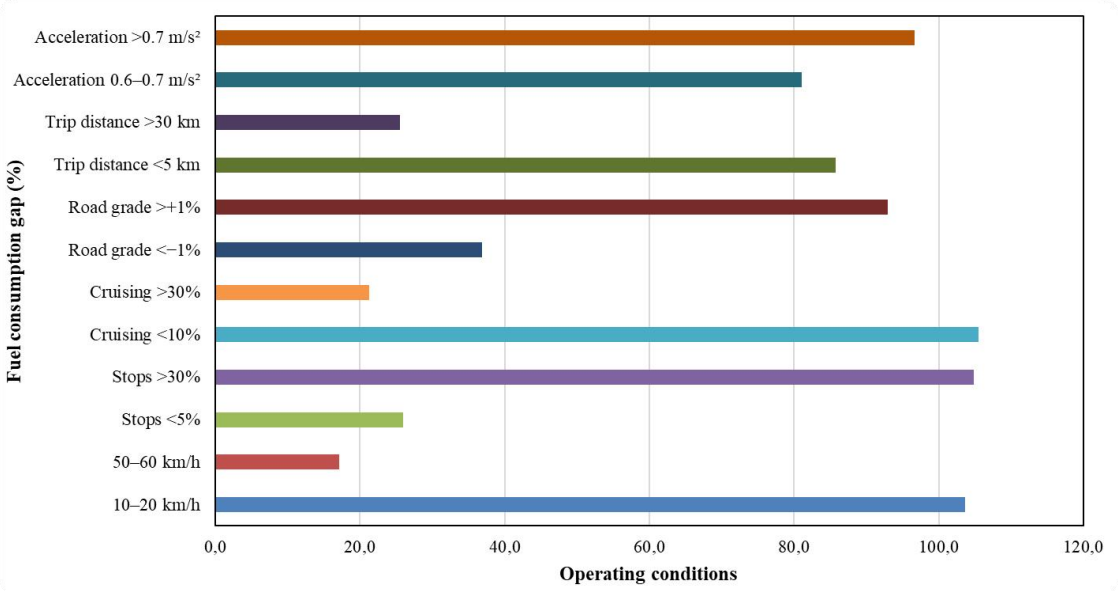



**Figure 1. Fuel consumption gap under different real-world operating conditions**

Traffic intensity also had a substantial effect on fuel consumption. When the proportion of vehicle stops was less than 5%, the fuel consumption gap was 26.0±22.6%, whereas increasing the proportion of stops to more than 30% increased this value to 104.8±48.0%. At the same time, increasing the proportion of steady cruising from less than 10% to more than 30% reduced the fuel consumption gap from 105.5±36.3% to 21.3±16.7%. This demonstrates that frequent stopping and subsequent acceleration under congested traffic conditions significantly reduce fuel efficiency.

Road gradient was also identified as an important factor. When the road gradient was below −1%, the fuel consumption gap was 36.9±34.0%, while a gradient above +1% resulted in a substantially higher value of 93.0±35.3%. Trip distance also affected fuel consumption. For trips shorter than 5 km, the fuel consumption gap reached 85.8±44.3%, whereas for trips longer than 30 km, it decreased to 25.5±14.2%. This indicates that short-distance trips can result in considerably higher fuel consumption, particularly when the engine has not yet reached its optimal operating temperature.

**Table 1. Fuel consumption gap under different real-world operating conditions**

| № | Operating factor | Condition/value | Fuel consumption gap (%) |
|---|---|---|---|
| 1 | Average vehicle speed | 10–20 km/h | 103.6±47.1 |
| 2 | Average vehicle speed | 50–60 km/h | 17.1±18.9 |
| 3 | Vehicle stops | <5% | 26.0±22.6 |
| 4 | Vehicle stops | >30% | 104.8±48.0 |
| 5 | Cruising operation | <10% | 105.5±36.3 |
| 6 | Cruising operation | >30% | 21.3±16.7 |
| 7 | Road gradient | <−1% | 36.9±34.0 |
| 8 | Road gradient | >+1% | 93.0±35.3 |
| 9 | Trip distance | <5 km | 85.8±44.3 |
| 10 | Trip distance | >30 km | 25.5±14.2 |
| 1 | Average positive | 0.6–0.7 m/s² | 81.1 |

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| | | | |
|---|---|---|---|
| 1 | acceleration | | |
| 12 | Average positive acceleration | >0.7 m/s² | 96.7 |

Driving style produced a noticeable effect as well. An average positive acceleration of 0.4–0.6 m/s² corresponded to a normal driving regime and a fuel consumption gap of 41.0–53.4%. When acceleration increased to 0.6–0.7 m/s², the corresponding value reached 81.1%, while acceleration above 0.7 m/s² resulted in 96.7%. Therefore, aggressive driving characterized by intensive acceleration substantially increases fuel consumption.

Based on these findings, the most effective measures for reducing fuel consumption are maintaining a stable vehicle speed, minimizing unnecessary stops, avoiding sudden acceleration and braking, and selecting a driving regime appropriate to road and traffic conditions. The obtained results provide a practical basis for assessing fuel consumption under real operating conditions and developing an effective method for improving vehicle fuel efficiency.

## CONCLUSION

The study established that automobile fuel consumption under real operating conditions is strongly influenced by vehicle speed, traffic intensity, road gradient, trip distance, and driving behavior. The results showed that frequent stops, low-speed operation, short trips, and intensive acceleration contribute to increased fuel consumption. In particular, the fuel consumption gap reached 103.6±47.1% at average speeds of 10–20 km/h, while the most favorable result was observed at 50–60 km/h, where the gap was 17.1±18.9%. Increasing the proportion of vehicle stops from less than 5% to more than 30% also resulted in a substantial increase in the fuel consumption gap. These findings confirm the importance of maintaining stable vehicle movement and avoiding unnecessary changes in driving conditions.

The study also demonstrated that driving behavior is an important factor in improving fuel efficiency. Average positive acceleration above 0.7 m/s², corresponding to more dynamic driving, resulted in a fuel consumption gap of 96.7%, whereas moderate acceleration produced considerably lower values. Based on the obtained results, fuel consumption can be reduced by maintaining an appropriate and stable speed, minimizing unnecessary stops, avoiding sudden acceleration and braking, and selecting driving modes according to road and traffic conditions. The identified relationships provide a practical basis for developing fuel-saving strategies and improving the efficiency of automobile operation under real-world conditions.

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