EVALUATION OF AIR-FUEL RATIO AND VEHICULAR EMISSIONS OF DIFFERENT EFI PETROL VEHICLES IN LAHORE, PAKISTAN

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ABSTRACT: This study investigates the impact of air fuel ratio on EFI based petrol vehicles emission by On-Board Diagnostics (OBD) in Lahore, Pakistan. Vehicular Emission tests like CO, HC, NO, SO_2, and CO_2were performed using advanced analyzers at authorized workshops. It was observed that whenever the sum of Long-Term Fuel Trim (LTFT) and Short-Term Fuel Trim (STFT) values and Carbon Monoxide (CO) emissions, with vehicles having LTFT + STFT values between -10 and +10 consistently passing emission tests. Euro V vehicles showed the lowest emissions (CO <100 ppm, negligible HC), Euro IV vehicles had moderate emissions (CO ≤300 ppm, HC ≤2000 ppm), while Euro II vehicles, especially older models, exhibited the highest (CO ≤12000 ppm, HC ≤6000 ppm). OBD scanners can serve as an efficient preliminary screening tool to streamline emission testing in regions with limited infrastructure.

Key Words: OBD Scanner, Fuel Trim, Air Fuel Ratio, Emissions, Vehicles, Lahore

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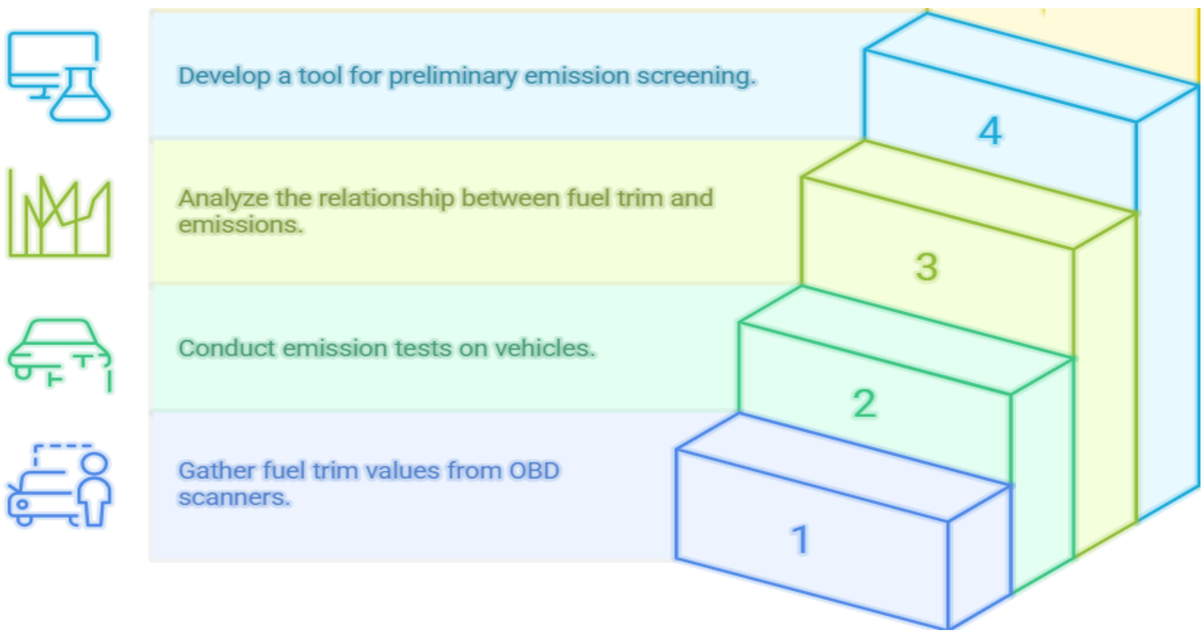


INTRODUCTION

Lahore, Pakistan's second-largest city, faces severe air pollution, with vehicular emissions contributing significantly to elevated levels of Particulate Matter ($PM_{2.5}$, PM_{10}), Nitrogen Oxides (NO_x), Carbon Monoxide (CO), and Volatile Organic Compounds (VOCs) (Ali *et al*., 2022). Traffic congestion, inefficient fuel combustion, and lax emission regulations exacerbate the issue, particularly during winter smog (Ahmed *et al*., 2023).

The optimal control of internal combustion engines is paramount for achieving both fuel efficiency and reduced harmful emissions, a challenge that has become increasingly stringent with evolving environmental regulations (Akunov, 2024; Romero *et al*., 2024). A cornerstone of this optimization lies in precisely managing the air-fuel ratio (AFR), which directly influences combustion efficiency and the composition of exhaust gases (Yasui *et al*., 2012; Al-Himyari *et al*., 2014). Modern automotive electronic control units (ECUs) continuously monitor and adjust the AFR to maintain it near the stoichiometric ideal (λ=1), where catalytic converters operate most effectively to minimize pollutants like hydrocarbons (HC), carbon monoxide (CO), and nitrogen oxides (NOx) (Akunov, 2024; Yasui *et al*., 2012). These real-time adjustments are primarily performed through fuel trims, specifically short-term fuel trim (STFT) and long-term fuel trim (LTFT), which represent the instantaneous and learned corrections to fuel injection duration, respectively, based on feedback from oxygen sensors (Akunov, 2024; Leshchenko, 2007). A critical task within this domain involves experimentally testing the direct effect of varying air-fuel ratios on the resulting exhaust emissions, quantifying how deviations from optimal AFR impact the release of pollutants into the atmosphere. Furthermore, the accurate estimation and control of fuel consumption, often utilizing real-time On-Board Diagnostics (OBD) data and advanced machine learning models, are vital for fleet management and further reducing the environmental footprint of vehicles (Ansari *et al*., 2022). This intricate interplay between AFR control, fuel trim mechanisms, and emission reduction strategies forms the core of modern engine management systems, continuously striving for a balance between performance and environmental responsibility).

Additionally, catalytic converters play a vital role in emission reduction by converting harmful pollutants into less toxic gases. However, their efficiency declines if vehicles are not regularly serviced or if low-quality fuel is used (Mehmood *et al*., 2021). Ensuring that vehicles meet proper emission standards through routine checks and tune-ups is essential for maintaining urban air quality.

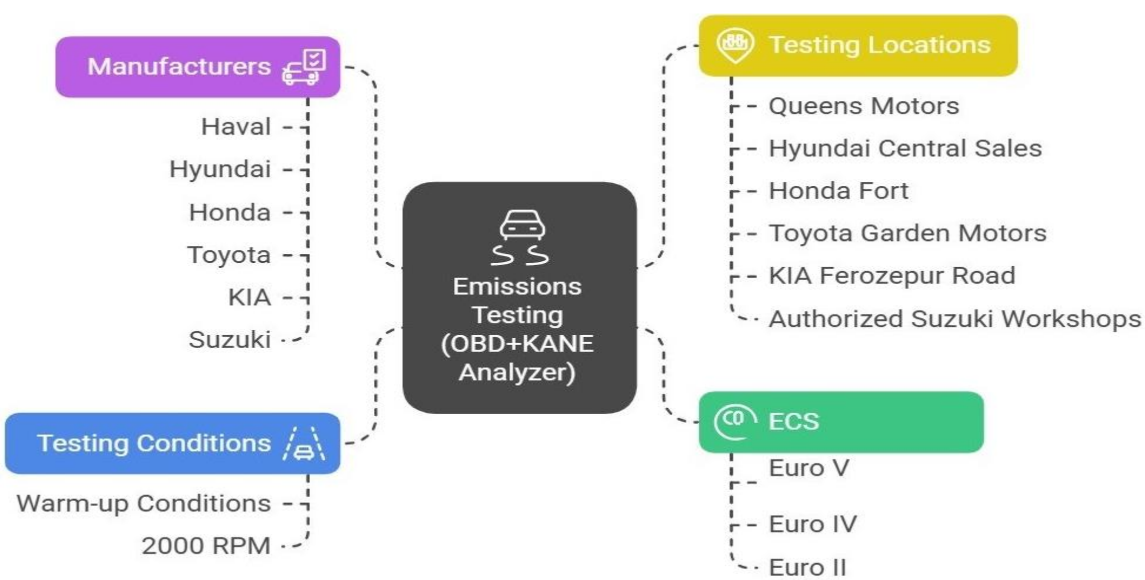
It is observed that for Electronic Fuel Injection (EFI) vehicles, an on-board diagnostic (OBD) scanner can be used to assess emissions. If the readings of Long-Term Fuel Trim (LTFT) and Short-Term Fuel Trim (STFT) indicate an appropriate air-fuel ratio, the vehicle generally exhibits lower exhaust emissions. There is need to study the appropriate values of LTFT and STFT to lower the emissions of vehicles. This method provides a real-time assessment of combustion efficiency, allowing for timely adjustments that help reduce emissions.

METHODOLOGY

This study evaluated emissions from EFI petrol vehicles (2010–2025 models) that meet Euro V, IV, and II standards, excluding motorcycles, diesel vehicles, and carbureted vehicles due to OBD scanner compatibility. Testing took place at authorized workshops in Lahore, including:

- **Haval (Euro V)**: Queens Motors, 19-A, Queens Road.
- **Hyundai (Euro V)**: Hyundai Central Sales, 75-A, Gulberg III.
- **Honda (Euro IV)**: Honda Fort, 32 Queen's Road.
- **Toyota (Euro IV)**: Toyota Garden Motors, 10-L Ferozepur Road.
- **Kia (Euro II)**: KIA Ferozepur, 2–5 M Block, Gulberg III.
- **Suzuki (Euro II)**: Authorized Suzuki workshops.

Emissions (CO, HC, NO, SO2, CO2) were measured using Kane Automotive and MRU Analyzers from Pak Green Lab. OBD scanners retrieved LTFT and STFT values to assess combustion efficiency. Vehicles were tested under warm-up conditions (coolant >90°C) at approximately 2000 RPM to simulate urban driving. Data were categorized by Euro standard and manufacturer for comparative analysis, ensuring reliable insights into emission control effectiveness.



The testing procedure involved a standardized approach to ensure consistent and reliable results. Vehicles were categorized based on their Euro emission standard (Euro V, Euro IV, and Euro II) and manufacturer, allowing for comparisons across different technological levels and brands. To simulate real-world driving conditions, vehicles were tested under warm-up conditions, with coolant temperatures exceeding 90°C. During testing, the engine speed was maintained around 2000 RPM to replicate idle and low-load driving scenarios, which are common in urban environments.

By collecting and analyzing data on various emission parameters across different vehicle categories, this study aimed to assess the effectiveness of Euro emission standards in controlling vehicular pollution and identify potential areas for improvement in vehicle technology and emission control strategies. The use of multiple testing instruments and a standardized testing procedure ensured the accuracy and reliability of the findings, providing valuable insights for policymakers and stakeholders involved in air quality management.

RESULTS

The test results of various vehicles evaluated emissions from Electronic Fuel Injection (EFI) petrol vehicles compliant with Euro V, Euro IV, and Euro II standards in Lahore, Pakistan, focusing on Carbon Monoxide (CO) and Hydrocarbon (HC) emissions, along with On-Board Diagnostics (OBD) scanner fuel trim values. Testing was performed under standardized conditions (coolant temperature >90°C, engine speed approximately 2000 RPM) using Kane Automotive and MRU Analyzers. Results are organized by Euro standard, followed by OBD scanner findings, with key data summarized in Table 1 and Figure 2.

Table 1: Comparison of emissions from different brands of vehicles

Vehicle types	Manufacturer	CO (ppm)	HC (ppm)
Euro V	Haval and Hyundai	< 100	Negligible
Euro IV	Toyota	< 100	< 100
Euro IV	Honda (Newer Models)	≤ 150	≤ 100
Euro IV	Honda (Older Models)	≤ 1000	≤ 2000
Euro IV	Changan	≤ 300	Negligible
Euro II	KIA	≤ 800	≤ 150
Euro II	Suzuki (Newer Models)	≤ 1400	≤ 2000
Euro II	Suzuki (Older Models)	≤ 12000	≤ 6000
BOSCH	Toyota &Changan (Euro IV)	< 100	N/A

The maximum CO and HC values were measured in Suzuki brand, which include Mehran, Swift, Cultus and Alto. The minimum CO and HC were measured in Haval and Hyundai. The range of fuel trims measured in seven brands of study remained within ± 10. The lowest emissions were measured in Euro V and IV cars.

DISCUSSION

Modern vehicles equipped with advanced emission control systems, such as catalytic converters, are designed to significantly reduce harmful pollutants from their exhaust. These systems efficiently convert toxic gases like carbon monoxide, hydrocarbons, and nitrogen oxides into less harmful substances. Consequently, newer vehicles, especially those adhering to stricter emission standards like Euro V, demonstrate substantially lower emission levels compared to older models that met Euro IV or Euro II standards, reflecting continuous advancements in automotive technology and environmental regulations. Beyond technological improvements, regular and proper vehicle maintenance plays a crucial role in sustaining these low emission levels throughout a vehicle's lifespan. Well-maintained engines operate more efficiently, ensuring optimal combustion and preventing increases in harmful emissions that can arise from neglected components or improper functioning.

Euro V vehicles outperformed Euro IV and II vehicles, with older Euro II vehicles (e.g., Suzuki) exhibiting significantly higher emissions. Figure 2 illustrates these trends, with CO emissions plotted against vehicle categories, highlighting the superior performance of Euro V vehicles and the substantial emissions from older Euro II models.

Haval and Hyundai vehicles (Euro V) exhibited the lowest emissions, with mean CO levels below 100 ppm (range: 50–90 ppm, n=10 vehicles) and HC emissions near detection limits (<10 ppm). These results reflect the efficacy of advanced emission control technologies, such as catalytic converters, in meeting stringent standards.

Toyota (Euro IV) vehicles demonstrated low emissions, with mean CO levels below 100 ppm (range: 60–95 ppm, n=12) and HC emissions below 100 ppm (range: 20–80 ppm). Honda Euro IV vehicles showed variability: newer models (2018–2025) had mean CO emissions of 120 ppm (range: 100–150 ppm, n=8) and HC emissions below 100 ppm, while older models (2010–2017) recorded higher values, with mean CO of 800 ppm (range: 500–1000 ppm, n=6) and HC up to 2000 ppm. Changan (Euro IV) vehicles had mean CO emissions of 250 ppm (range: 200–300 ppm, n=7) and HC emissions below 10 ppm. Independent testing at BOSCH Lab confirmed low CO emissions (<100 ppm) for Toyota and Changan Euro IV vehicles (n=5).

Kia (Euro II) vehicles recorded higher emissions, with mean CO levels of 600 ppm (range: 400–800 ppm, n=9) and HC emissions up to 150 ppm (range: 100–150 ppm). Suzuki Euro II vehicles showed the highest emissions, particularly older models (2010–2015), with mean CO emissions of 10,000 ppm (range: 8000–12000 ppm, n=6) and HC emissions up to 6000 ppm (range: 4000–6000 ppm). Newer Suzuki models (2016–2025) had lower emissions, with mean CO of 1200 ppm (range: 1000–1400 ppm, n=8) and HC up to 2000 ppm. These values, while within the current PEQS limit of 6% (60,000 ppm) for CO, highlight the poor emission control of older Euro II vehicles.

Although there is no direct relation-ship between fuel trims and emissions in literature, but in this study, a key finding regarding vehicle emissions performance was observed that vehicles exhibiting combined Long-Term Fuel Trim (LTFT) and Short-Term Fuel Trim (STFT) values within the range of -10% to +10%, coupled with all associated sensors functioning correctly and the absence of any "Check Engine" light (Diagnostic Trouble Codes or DTCs), were consistently found to be meeting the Punjab Environmental Quality Standards (PEQS) for Carbon Monoxide (CO) emissions. This indicates that maintaining the engine's fuel delivery within this optimal trim range, alongside proper sensor operation and no fault codes, is a reliable indicator of compliance with CO emission standards.

All tested vehicles provided oxygen sensor readings, confirming efficient combustion when fuel trim values were within this range. Deviations beyond ±10 were associated with elevated CO emissions, particularly in older Euro II vehicles.

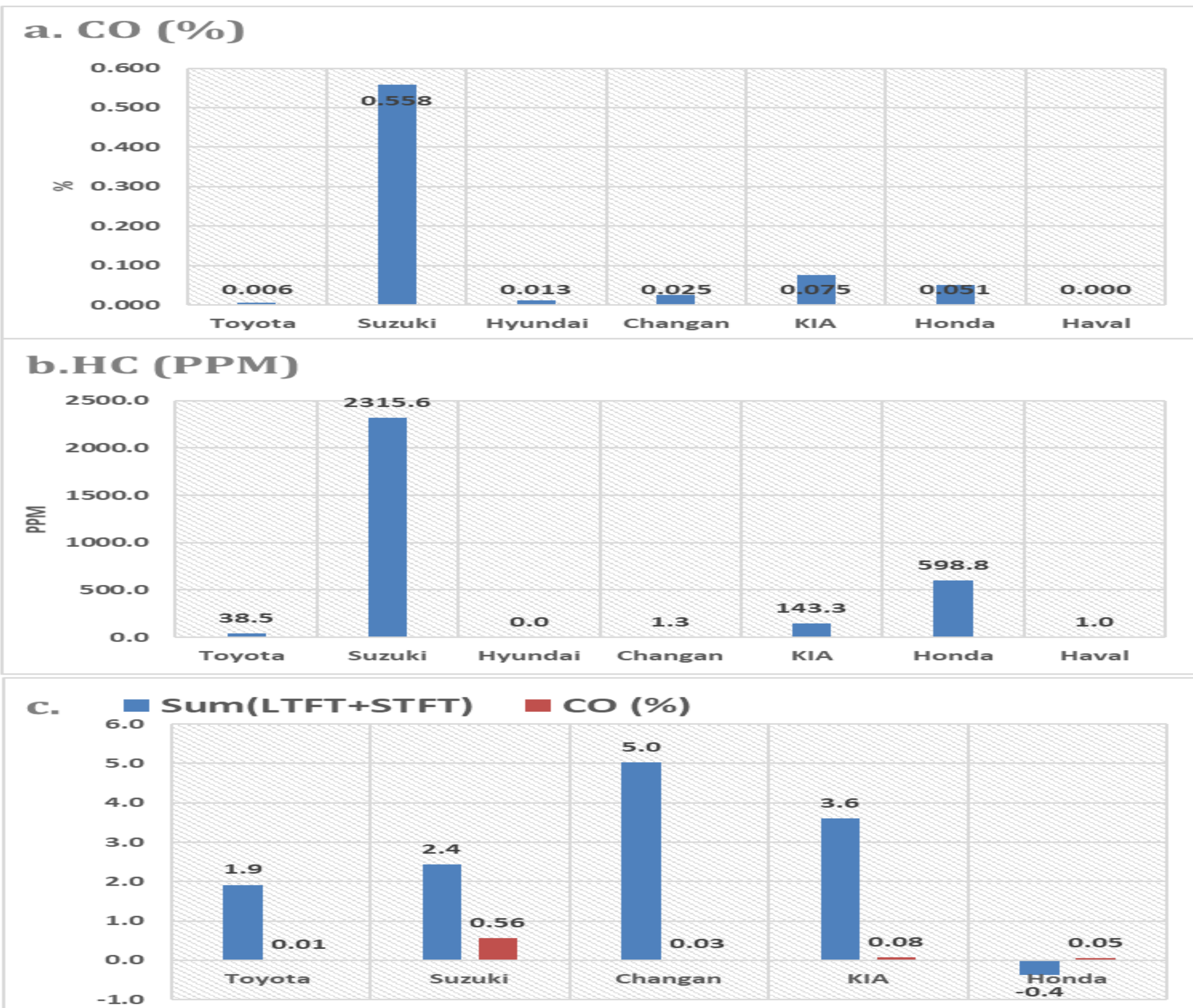


Figure 2: Comparison of a. CO emissions, b. HC emissions from different vehicle brands and c. Sum of LTFT Vs CO%

Conclusion: In this study, it was concluded that vehicles with combined LTFT and STFT values between -10 and +10 in combination with all sensors working properly and no engine check light (DTCs), were found meeting PEQS for CO emissions, confirming that whenever the air fuel ratio is optimum, vehicles likely to comply vehicle emissions test. OBD scanners can serve as a preliminary screening tool to identify compliant EFI petrol vehicles, reducing the need for comprehensive emission testing and conserving resources in high-traffic populated regions like Lahore.

Recommendations: On the basis of this study, it is inferred that On Board Diagnostic Tool (OBD)is useful to scan the EFI petrol automotive for compliance and non-compliance of PEQS. The workshops used in this study need training/orientation session to use such diagnostic tools/scanners for vehicular emission oriented testing. There is need to have data storage of these test records, which include reporting system on a dedicated portal or online drive. The present standards of in-use vehicles are limited to only three parameters i.e. smoke opacity, CO and noise. Therefore it is the need of the hour to revise these standards for in-use vehicles to include HCs in the emission standards. The present standards for Smoke opacity and CO are too much relaxed and there is need to make them stringent.

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