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The Influence of Low Tyre Pressure on Fuel Consumption and CO_2 Emissions: A Practical Experiment in Libya

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ABSTRACT

This study examines the relationship between tyre pressure, fuel consumption, and CO_2 emissions in Libya, a region where transport emissions were substantial at 16 $MtCO_2e$ in 2012. Conducted between November 2021 and May 2022 along the Libyan coast, specifically from Tripoli to Abu Qurayn, the research involved four distinct vehicle types (Cases A–D) with varied tyre specifications. Experimental findings demonstrate a significant inverse correlation: increased tyre pressure consistently led to reduced fuel consumption and CO_2 emissions. Quantitatively, increasing tyre pressure by 0.8 bar (from 1.2 to 2 bars) resulted in an overall reduction of up to 55% in both fuel consumption and total CO_2 emissions. Case A, for instance, showed a remarkable 54.72% reduction, with average fuel consumption dropping from 18.62 L/100 km to 8.34 L/100 km, and emissions decreasing to 5.40 $MtCO_2e$. Similar significant efficiencies were observed across all tested vehicle cases.

تأثير انخفاض ضغط الإطارات على استهلاك الوقود و انبعاثات ثاني أكسيد الكربون في المركبات: تجربة عملية في ليبيا

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الكلمات المفتاحية:
ضغط الإطارات.
استهلاك الوقود.
نسبة التخفيض.
المواصلات.
ترشيد الإستهلاك.

الملخص

تبحث هذه الورقة في تأثير تغيير ضغط الإطارات على استهلاك الوقود وانبعاثات ثاني أكسيد الكربون في ليبيا، وهي منطقة وصلت فيها انبعاثات النقل إلى 16 مليون طن من مكافئ ثاني أكسيد الكربون في عام 2012. أجريت الدراسة من نوفمبر 2021 إلى مايو 2022، وكان موقع الدراسة على الساحل في ليبيا بين طرابلس ومدينة أبو قرين. باستخدام أربعة أنواع مميزة من المركبات، مصنفة إلى الحالات أ، ب، ج، ود، ولكل منها مواصفات إطارات مختلفة. كشفت النتائج التجريبية عن وجود ارتباط خطي سلبي كبير: مع زيادة ضغط الإطارات، ينخفض كل من استهلاك الوقود وانبعاثات ثاني أكسيد الكربون. على وجه التحديد، أدى رفع ضغط الإطارات من 1.2 بار إلى 2 بار (بفارق 0.8 بار) إلى انخفاض عام في استهلاك الوقود وانبعاثات ثاني أكسيد الكربون الإجمالية بنسبة تصل إلى 55٪. في الحالة أ، لوحظ انخفاض ملحوظ بنسبة تصل إلى 54.72%، حيث انخفض متوسط استهلاك الوقود من 18.62 لتر/100 كم إلى 8.34 لتر/100 كم، وانخفضت الانبعاثات إلى 5.40 مليون طن مكافئ من ثاني أكسيد الكربون. ولوحظت انخفاضات مماثلة في جميع الحالات المختبرة.

1. Introduction

Global economic growth and rising incomes have led to a substantial increase in vehicle ownership and, consequently, atmospheric emissions. This trend is particularly evident in Libya, where registered vehicles dramatically increased from 465,000 in 1983 to 2,680,000 by 2014 [1]. As a result, transport emissions have become a major contributor to air pollution, with total carbon dioxide equivalent (CO_2e) emissions from this sector escalating from 6.12 $MtCO_2e$ in

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1990 to 16 $MtCO_2e$ by 2012 [16]. While numerous factors influence these emissions, this paper specifically investigates the critical role of tyre pressure. Proper tyre pressure is essential for vehicle safety and performance. Deviations from recommended pressure levels cause tyre deformations that directly affect vehicle stability, tyre wear patterns (e.g., irregular tread wear due to over- or under-inflation [3–4]), and overall tyre longevity. As Figure 1 illustrates, insufficient tyre pressure (Case A) results in inward deformation and reduced tyre life. Conversely, excessive pressure (Case B) leads to increased road vibrations and diminished damping capacity, potentially compromising driving safety. Maintaining the correct tyre pressure (Case C), however, ensures optimal fuel consumption, enhances driving comfort by mitigating vibrations, extends tyre lifespan, and shortens braking distances [5].

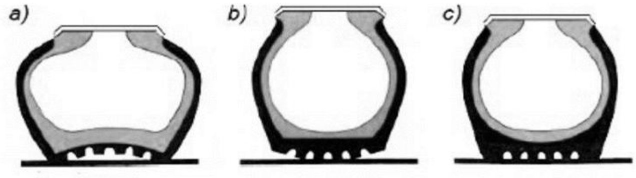

Fig. 1: Reason of tire deformation in a) a low pressure, b) high pressure, c) proper pressure [3].

The primary aim of this study is to investigate the effects of low tire pressure on fuel consumption and its subsequent correlation with exhaust CO2 emissions from vehicles.

2. Literature Review

Research consistently highlights the critical role of tire pressure in vehicle performance and efficiency. For instance, Caban, Jacek, et al. [6] demonstrated that maintaining optimal tire pressure and temperature can extend tire life by up to 30%, identifying improper pressure as a primary cause of tire damage. Similarly, M. Egger [7] reported an even more significant extension of 50% in tire lifespan with correct pressure. Conversely, Reiter, Marc, et al. [8] found that vehicles operating with lower tire pressure experienced a reduction in tire life by up to 5%.

Beyond tire longevity, numerous studies have explored the direct relationship between tire pressure, rolling resistance, and fuel consumption. Varghese and Schmitz [9] clearly indicated that increasing tire pressure reduces rolling resistance. This aligns with Jansen's [10] finding that a 0.03 MPa decrease in tire pressure led to a 6% increase in rolling resistance, which in turn caused a 1% increase in fuel consumption. Emphasizing the significance of rolling resistance, Baglione et al. [11] showed it accounts for up to 15.5% of the total energy consumption in a full-size pickup truck.

Further demonstrating the impact on fuel economy, Thomas et al. [12] investigated three common vehicles (a 2009 Ford Explorer, a 2009 Toyota Corolla, and a 2009 Honda Odyssey Minivan), concluding that low tire pressure increased fuel consumption by up to 10%. In a similar vein, Guillou et al. [13] reported increases in both fuel consumption and rolling resistance when tire pressure was suboptimal. While most studies focus on the negative impacts of low pressure, D'Ambrosio and Vitolo [14] utilized computer simulations to explore how optimized lower tire pressures could paradoxically improve rolling resistance, showing a potential fuel consumption reduction of up to 2% in highway driving.

More recently, Synak and Kalasova [15] explicitly linked rolling resistance to tire pressure, directly influencing fuel consumption. Their research, conducted on a Skoda Fabia 1.9 TDi (Continental Winter Contact TS 860 tires, 195/65 R15 91 T), underscored the importance of maintaining correct tire pressure. Their findings revealed that improper pressure forced the engine to consume more fuel to overcome increased rolling resistance, consequently leading to higher emissions.

Recent investigations further corroborate these findings. A study by Bauer and Maier [20] indicated that maintaining standard tire pressure can reduce fuel consumption by up to 2% in real-world driving conditions, and highlighted how under-inflated tires consistently increase rolling resistance and negatively impact fuel economy. Additionally, a publication by JACO Superior Products [21] emphasizes that tire pressure, though often overlooked, significantly impacts fuel efficiency, aligning with findings from the U.S. Department of Energy, which suggest under-inflated tires can reduce fuel economy by up to 3% due to increased rolling resistance.

3. Location

While the specific location was not critical to the mechanics of the experiment, maintaining a consistent location was essential to ensure comparability of the results. The study was conducted along the coastal region of Libya, between Tripoli and the city of Abu Qurayn a distance of approximately 350 km, as estimated using Google Maps. The city of Garabulli, located around 60 km east of Tripoli, also formed part of the experimental route, as illustrated in Figure 2.

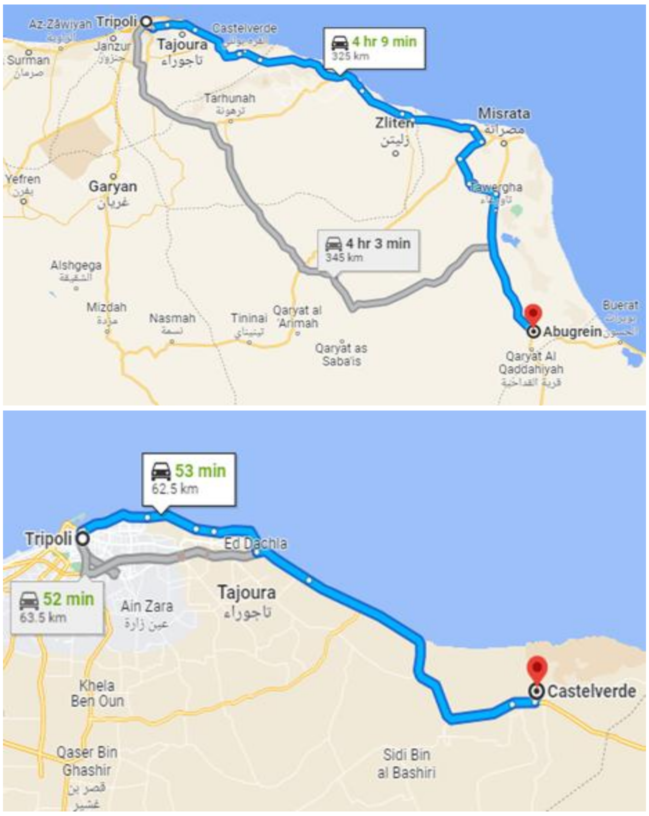

Fig. 2: The path of the coastal line in Libya (the experiment location)[18-19]

The study employed an experimental methodology. A pressure tire gauge was used to accurately determine the tire pressure. Fuel consumption was quantified as liters per 100 kilometers (L/100 km), calculated by measuring the volume of fuel consumed from the tank over a recorded travel distance.

Experiments were conducted using various types of vehicles, whose specifications are detailed in Table 1. The selection of these particular vehicles was based on their availability for testing and their prevalence within the Libyan car market.

Fig. 3: the size of engines for testing vehicles.

Fig. 4: specification data vehicles using dashboards.

Table 1: specifications of tires and data vehicles.

	of vehicle Type	Case	Man. date	cyl.	Eng.	Tire specification
1	Hyundai Sonata	A	2007	4	2000_{CC}	215/60 R15 V 95
2	Hyundai Elantra	B	2009	4	2000_{CC}	215/60 R15 V 95
3	Hyundai Sonata	C	2002	4	2700_{CC}	215/60 R16 V 95
4	Toyota Camry	D	2004	4	2400_{CC}	195/65 R15 91 T

Fig. 5: Specifications of data for tires

4. Addressing Experimental Challenges

Conducting this experiment presented several challenges, including variations in road conditions, weather, and vehicle maintenance. To ensure comparable results, these factors were assumed constant due to the short duration between experiments, the use of the same road segments, and consistent weather season.

Furthermore, driver behavior significantly influenced experimental results, both in city and highway driving. To simplify the analysis and minimize variability, fuel tank refills and tire inflation adjustments were performed during a single service event for each test instance.

5. Data Analysis

For each experimental instance, regression analysis was employed to determine the correlation between tire pressure and fuel consumption rate, enabling the calculation of fuel consumption percentages and CO2 emissions. Additionally, the reduction rate for fuel consumption and emissions was determined using results extracted from charts and the following equations:

$$R\,(\%) = \frac{\mathrm{FUEL_{CONSMPUTION}} - \mathrm{FUEL_{CONSMPUTION\_PROP}}}{\mathrm{FUEL_{CONSMPUTION}}} \times 100 \quad (1)$$

$$R\,(\%) = \frac{\mathrm{CO2_{emission}} - \mathrm{CO2_{emission-opt}}}{\mathrm{CO2_{emissiont}}} \times 100 \quad (2)$$

a. Study Variables

This research investigated the relationship between the following key variables:

- Average tire air pressure (bar): Independent variable
- Average fuel consumption (L/100 km): Dependent variable

b. Experiment

The experimental phase of this study was conducted from November 2021 to May 2022, accumulating over 5000 km of road testing. Data for all vehicle tires were meticulously recorded, including average tire pressure and corresponding fuel consumption. To ensure reliable data, only fuel consumption values from routes exceeding 50 km were considered for analysis. Each experiment's data was subsequently compiled into a chart, which included the regression curve and its associated R^2 coefficient.

Fig. 6: Measurement of tire pressure (bar) using a gauge.

c. Vehicle Emissions Footprint Calculator Online Software

An online software tool was utilized to determine the exhaust emissions (kg) produced by the vehicles. This program calculates emissions by simply multiplying the fuel consumption rate (L/100 km) by the total travel distance (km) [17]. This method is a widely adopted approach in similar experimental studies.

d. Limitations and Potential Improvements

This study encountered several limitations, including the specific type of fuel utilized, potential minor errors in tire pressure measurements, and the representativeness of the vehicle sample. While these parameters were controlled to be as accurate as possible and are not believed to significantly skew the current results, they represent areas for future enhancement. Future experiments could benefit from incorporating a wider variety of fuel types, employing more advanced pressure measurement techniques, and expanding the diversity and size of the vehicle fleet to enhance the generalizability of the findings.

6. Results and Discussion

a. Influence of Tire Pressure on Fuel Consumption

To analyze the relationship between average fuel consumption (L/100 km) and average tire air pressure (bar), data for each of the four cases (A, B, C, and D) was plotted. Linear regression analysis was then applied to derive a curve equation and determine the R^2 coefficient for each case.

For Case A, the experimental results, illustrated in Figure 7, clearly show that increasing average tire pressure leads to a decrease in fuel consumption, which in turn results in reduced emissions (Table 2). Specifically, the relationship for vehicle A is described by the regression equation F(x) = -12.56x + 34.84, where F(x) represents fuel consumption in L/100 km. The calculated R^2 coefficient of 0.701 indicates a moderate positive correlation, suggesting that tire pressure is a significant factor in fuel efficiency.

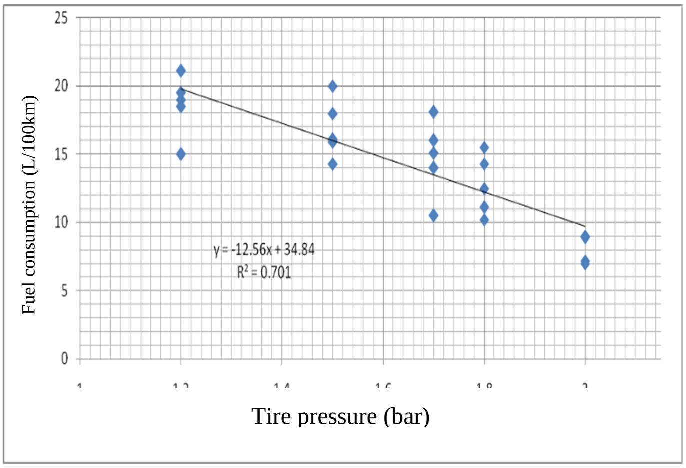

Fig. 7: illustrates the calculated R^2 coefficient of 0.701

As presented in Table 2, the Significance F value for the regression model is 7.13×10^{-7}. Since this value is considerably less than 0.05 ($p < 0.05$), it strongly indicates that the relationship between the independent and dependent variables is statistically significant, confirming a genuine correlation rather than one due to random chance.

Table 2: The R^2 coefficient and the equation of this curve were calculated vehicle A

SUMMARY OUTPUT						
Regression Statistics						
Multiple R		0.824827				
R Square		0.701232				
Adjusted R Square		0.66581				
Standard Error		2.282135				
Observation.		24				
ANOVA	df	SS	MS	F	Significant F	
Regression	1	243.8609	243.860	46.8230	7.13E-07	
Residual	22	114.579	5.20814			
Total	23	358.44				
Upper 95%	Lower 95%	P-value	t Stat	Standard Error	Coefficient	
39.8059	27.9361	5.1E-11	11.83577	2.86175	34.84	Inter-cept
-8.2863	-15.493	7.1E-07	-6.84274	1.737588	-12.56	2

Table 3: Fuel consumption level of L/100 km and CO_2 emission reduction (kg) vehicle A

Data	Experiment 1	Experiment 2	Experiment 3	Experiment 4	Experiment 5	Unit
Travel distance	50	50	50	50	50	Km
Average tire Pressure	1.2	1.5	1.7	1.8	2	bar
Test 1	19	20	16	12.5	7.2	L/100km
Test 2	21.1	18	18.1	14.3	8.9	L/100km
Test 3	18.5	16.1	15.1	10.2	9	L/100km
Test 4	19.5	15.9	14	15.5	7.6	L/100km
Test 5	15	14.3	10.5	11.1	9	L/100km
Average fuel consumption	18.62	16.86	14.72	12.75	8.34	L/100km
Average CO_2 emission	44.5	40.3	35.18	30.47	20.15	kg
Average CO_2 Emission	0.445	0.403	0.3518	0.3047	0.201	kg/km
Number of vehicles in Libya	2,680,000			vehicle		
Total Emission in Libya by vehicle motor	11.926	10.8	9.428	8.165	5.400	MtCo2e
Reduction in CO_2 and fuel consumption from the first to fifth experiments due to a pressure difference of 0.8 bar					54.72%	

In vehicle B, using liner regression as shown in Figure 8, the indicated R^2 coefficient was equal to 0.739, indicating the lowest correlation value for the analyzed vehicle compared to other cases, even though it has a high correlation between variables. In addition, the CO_2 emissions and fuel consumption for Case B in Table 4 can be calculated using F(x) =-14.56X+38.81.

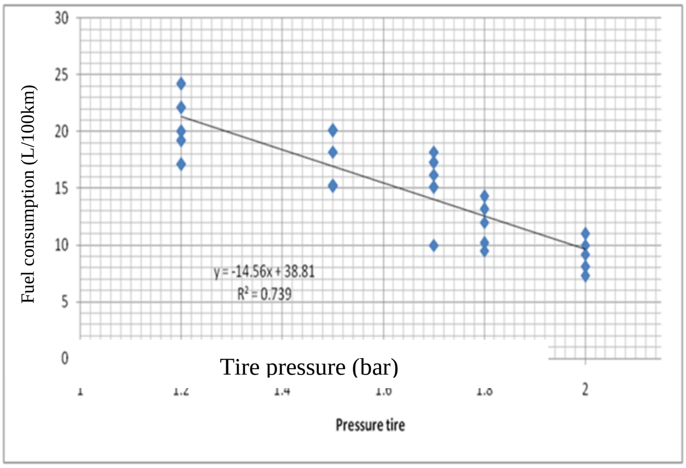

Fig. 8: Displays the calculated R^2 coefficient of 0.739.

As Table 4 shows, the Significance F value for this regression model is 1.69×10^{-7}. Since this value is considerably less than 0.05 (p <

0.05), it strongly indicates a statistically significant relationship between the two variables, confirming their genuine correlation.

Table 4: Determining the R^2 coefficient and the equation of this curve were derived from vehicle B

SUMMARY OUTPUT						
Regression Statistics						
Multiple R			0.847913			
R Square			0.739125			
Adjusted R Square			0.706182			
Standard Error			2.490093			
Observations			24			
ANOV A	df	SS	MS	F	Significance F	
Regression	1	348.9	348.9	56.27	1.69E-07	
Residual	22	136.4	6.200			
Total	23	485.3				
Upper 95%	Lower 95%	P-value	t Stat	Standard Error	Coefficients	
44.7967	31.84	2. E-11	12.2724	3.12252	38.32101	Intercept
-10.29	-18.	1.E-07	-7.501	1.895	-14.22	2

Table 5: Fuel consumption level of L/100 km and CO2 emission reduction (kg) vehicle B

Data	Experiment 1	Experiment 2	Experiment 3	Experiment 4	Experiment 5	Unit
Travel distance	50	50	50	50	50	Km
Average tire Pressure	1.2	1.5	1.7	1.8	2	bar
Test 1	22.1	20.1	16.2	12	8.1	L/100km
Test 2	24.2	18.2	18.2	13.2	9.2	L/100km
Test 3	17.1	15.3	15.1	14.3	7.3	L/100km
Test 4	19.2	20.1	17.3	10.2	10	L/100km
Test 5	20	15.2	10	9.5	11	L/100km
Average fuel consumption	20.52	17.78	15.36	11.84	9.12	L/100km
Average CO_2 emission	49.04	42.49	36.71	28.3	21.8	kg
Average CO_2 Emission	0.4904	0.4294	0.3671	0.283	0.218	kg/km
Number of vehicles in Libya	2,680,000					vehicle
Total Emission in Libya by vehicle motor	13.14	11.38	9.838	7.584	5.84	$MtCO_2e$
Reduction in CO_2 and fuel consumption from the first to fifth experiments due to a pressure difference of 0.8 bar			55.5%			

For vehicles C and D, the analysis similarly indicated a moderate correlation for the R^2 coefficient. Specifically, the R^2 value was 0.714 for vehicle C and 0.785 for vehicle D, as detailed in Table 6.8. Consistent with the other cases, Figures 9 and 10 demonstrate a negative linear correlation between tire pressure and fuel consumption for these vehicles

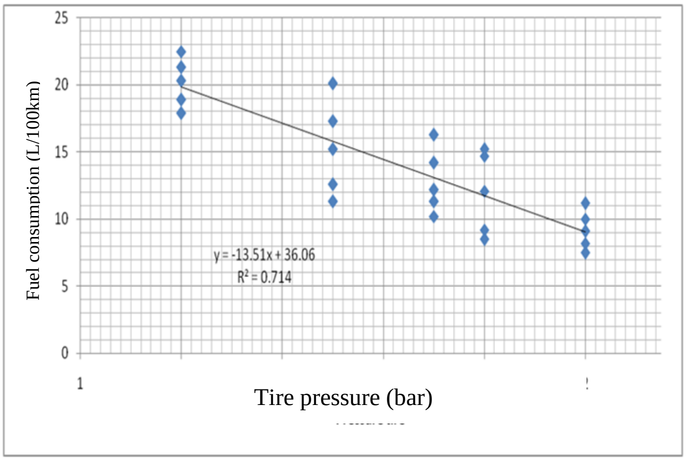

Fig. 9: The determined Coefficient R^2 was equal to 0.714 for C vehicle

Table 6. The R^2 coefficient and the equation of this curve were calculated vehicle C

SUMMARY OUTPUT						
Regression Statistics						
Multiple R			0.83199			
R Square			0.71425			
Adjusted R Square			0.678216			
Standard Error			2.46202			
Observations			24			
ANOVA	df	SS	MS	F	Significance F	
Regression	1	299.	299.9	49.476	4.66E-07	
Residual	22	133.				
Total	23	433.				
Upper 95%	Lower 95%	P-value	t Stat	Standard Error	Coefficients	
41.9875	29.18	8.E-11	11.52	3.0873	36.06	Intercept
-9.29793	-17.07	4.E-07	-7.03	1.8745	-13.5	2

Table 7: Determined a fuel consumption level of L/100 km and vehicle CO2 emission reduction (kg)

Data	Experiment 1	Experiment 2	Experiment 3	Experiment 4	Experiment 5	Unit
Travel distance	50	50	50	50	50	Km
Average tire Pressure	1.2	1.5	1.7	1.8	2	bar
Test 1	20.3	20.1	12.2	9.2	7.5	L/100km
Test 2	22.5	17.3	11.3	12.1	8.2	L/100km
Test 3	18.9	15.2	14.2	8.5	9.1	L/100km
Test 4	21.3	11.3	16.3	14.7	10	L/100km
Test 5	17.9	12.6	10.2	15.2	11.2	L/100km
Average fuel consumption	20.18	15.3	12.84	11.94	9.2	L/100km
Average CO_2 emission	48.23	36.57	30.69	28.54	21.9	Kg
Average CO_2 Emission	0.482	0.365	0.306	0.285	0.21	kg/km
Number of vehicles in Libya			2,680,000			vehicle
Total Emission in Libya by vehicle motor	12.92	9.8	8.22	7.64	5.89	$MtCO_2e$
Reduction in CO_2 and fuel consumption from the first to fifth experiments due to a pressure difference of 0.8 bar					54.4%	

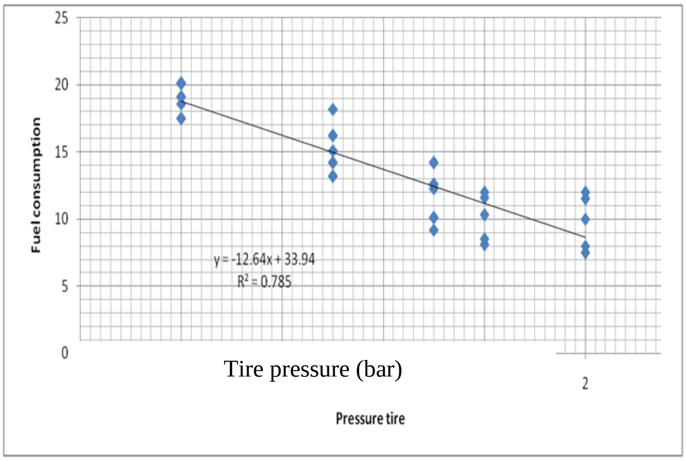

Fig. 10: Vehicle D's determined R^2 coefficient was 0.785

Table 8: Determining the R^2 coefficient and the equation of this curve were derived from vehicle D.

SUMMARY OUTPUT						
Regression Statistics						
Multiple R				0.877952		
R Square				0.785652		
Adjusted R Square				0.760381		
Standard Error				1.91221		
Observations			24			
ANOVA	df	SS	MS	F	Significance F	
Regression	1	270.5322	270.5322	73.98566	1.74E-08	
Residual	22	80.44407	3.656549			
Total	23	350.9763				
Upper 95%	Lower 95%	P-value	t Stat	Standard Error	Coefficients	
38.76056	28.8148	1.72E-12	14.09069	2.397872	33.94768	Intercept
-9.50377	-15.542	1.74E-08	-8.60149	1.455932	-12.6432	2

Table 9: Determined a fuel consumption (L/100km) and reduction CO_2 emission (kg) vehicle D

Data Case	Experiments A	B	C	D	Unit
Engine capacity	2000	2000	2400	2700	cc
Average tire pressure		2			bar
Travel distance		50			km
R-Square	0.701	0.739	0.714	0.785	
Average fuel	8.34	9.12	9.2	9.8	L/100km
Average Co_2 emission (kg)	20.15	21.8	21.99	23.42	kg
Average Co_2 emission (kg/km)	0.202	0.218	0.22	0.234	kg/km
Total Emission in Libya vehicle	5.4	5.84	5.89	6.27	$MtCO_2e$
Reduction in CO_2 and fuel consumption from the first to fifth experiments due to a pressure difference of 0.8 bar	54.72 %	55.54 %	%54.4	48.5%	

The table clearly indicates that larger engine capacities correlate with increased fuel consumption, consequently leading to higher emissions. The findings of this study strongly confirm a clear and significant inverse relationship between tire pressure, fuel consumption, and CO2 emissions in the tested vehicles. The remarkable reduction in fuel consumption and emissions observed when increasing tire pressure to recommended levels, reaching up to 55% in some cases, highlights that maintaining optimal tire pressure is a critical factor for enhancing the environmental and economic efficiency of vehicles.

This substantial effect can primarily be explained by the reduction in rolling resistance. When tire pressure is low, the contact patch between the tire and the road increases, leading to greater tire deformation and increased friction. This forces the engine to expend more energy to overcome this additional resistance, consequently increasing fuel consumption and emissions. Conversely, maintaining correct pressure reduces deformation and friction, allowing the vehicle to roll more efficiently.

Table 10 .Shows the calculated fuel consumption (L/100km) and emission reduction (kg)

Data	Experiment 1	Experiment 2	Experiment 3	Experiment 4	Experiment 5	Unit
Travel distance	50	50	50	50	50	Km
Average tire pressure	1.2	1.5	1.7	1.8	2	bar
Test 1	20.1	18.2	12.3	8.1	8	L/100km
Test 2	17.5	15.1	14.2	8.5	7.5	L/100km
Test 3	18.6	16.2	12.6	10.3	10	L/100km
Test 4	20.1	13.2	10.1	12	11.5	L/100km
Test 5	19.1	14.5	9.2	11.6	12	L/100km
Average fuel consumption	19.02	15.44	11.68	10.1	9.8	L/100km
Average CO_2 emission	45.46	36.9	27.92	24.14	23.42	Kg Co_2
Average CO_2 Emission	0.4546	0.369	0.2792	0.2414	0.2342	kg/km
Number of vehicles			2,680,000		vehicle	
Total Emission in Libya by vehicle motor	12.18	9.88	7.48	6.46	6.27	MtCo2e
Reduction in CO_2 and fuel consumption from the first to fifth experiments due to a pressure difference of 0.8 bar					48.5%	

These results align with previous research that has affirmed the relationship between tire pressure and fuel consumption. Studies such as those by Jansen [10] and Thomas et al. [12] reported increases in fuel consumption ranging from 1% to 10% due to low tire pressure. Our study, however, revealed significantly larger reductions of up to 55%. This notable discrepancy could be attributed to several factors; most notably, the very low starting tire pressure (1.2 bar) in our experiment compared to the levels that may have been used in other studies. Such extremely low initial pressures might indicate a common issue in vehicle maintenance within specific contexts, leading to a more pronounced improvement effect. Additionally, the environmental and operational conditions in Libya, such as ambient temperatures or road types, might also play a role in amplifying this effect compared to studies conducted in different environments.

These findings underscore the significant practical importance of maintaining correct tire pressure, particularly in regions like Libya where transportation sector emissions are markedly increasing. Raising awareness about the importance of regular tire pressure checks can lead to substantial national fuel savings, thereby alleviating economic burdens on individuals and contributing effectively to reducing overall carbon emissions.

Looking forward, additional research could focus on studying the long-term effects of tire pressure on vehicle performance and evaluating the economic and environmental benefits of implementing comprehensive national awareness programs. Furthermore, the impact of different tire types and driving styles on this relationship could be explored in greater detail.

7. Conclusion

This study investigated the impact of tyre pressure (bar) on fuel consumption (L/100 km) across four distinct vehicle cases (A, B, C, and D) in Libya. The findings consistently demonstrate that increasing tyre pressure to recommended levels significantly reduces fuel consumption, which in turn leads to a substantial decrease in CO_2 emissions. Specifically, the following observations were made:

Case A: Average fuel consumption decreased from 18.62 L/100 km to 8.34 L/100 km, resulting in a 54.72% reduction in fuel consumption and total emissions. Emissions fell from 11.93 $MtCO_2e$ to 5.40 $MtCO_2e$, supported by a strong correlation ($R^2 = 0.701$).

Case B: A similar increase in tyre pressure yielded a 55.54% reduction in fuel consumption and total emissions, with consumption dropping from 20.52 L/100 km to 9.12 L/100 km. Emissions reduced to 5.84 $MtCO_2e$ ($R^2 = 0.739$).

Case C: Fuel consumption and total emissions saw a 54.4% decrease, with consumption falling from 20.18 L/100 km to 9.2 L/100 km, corresponding to 5.89 $MtCO_2e$.

Case D: This case showed a 48.5% reduction in fuel consumption and emissions, with consumption decreasing from 19.02 L/100 km to 9.8 L/100 km. Emissions reached 6.27 $MtCO_2e$.

Across all cases, the R^2 values (ranging from 0.701 to 0.785) consistently indicate a moderate to strong negative linear correlation between tyre pressure and fuel consumption. These results highlight the critical importance of maintaining optimal tyre pressure as a practical and effective strategy for reducing fuel consumption and mitigating transport-related CO_2 emissions.

Nomenclature	Name of symbols	Unit
R	Reduction ration for CO_2emission	%
$FUEL_{CONSMPUTION\_PROP}$	Fuel Consumption at a proper tire pressure	L/100 km
$FUEL_{CONSMPUTION}$	Fuel Consumption at a lowest tire pressure	L/100 km
$CO_{2_{emission-opt}}$	CO_2 emission at a proper tire pressure	$MtCO_2kg$
$CO_{2_{emission}}$	CO_2 emission at a lowest tire pressure	$MtCO_2kg$

8. Recommendations

Based on this study's findings, the following recommendations are proposed to advance research and promote the practical application of maintaining optimal tyre pressure:

1. **Expand Research Scope:** Future studies should investigate tyre pressures beyond manufacturer-recommended values, exploring the potential impacts of over-inflation. Additionally, incorporating a wider range of environmental and road parameters (e.g., varying

temperatures, humidity, and diverse road surfaces) into experimental designs will further enhance the understanding of fuel efficiency under different real-world conditions.

2. **Facilitate Public Awareness and Accessibility:** For this research to yield tangible benefits, its findings must effectively reach and empower the public. This necessitates:

- **Public Awareness Campaigns:** Implement targeted educational campaigns to inform vehicle owners about the significant economic and environmental advantages of maintaining correct tyre pressure.
- **Policy Implementation:** Explore developing policy frameworks or regulations that encourage or mandate regular tyre pressure checks, ensuring widespread adoption of best practices.
- **Enhanced Infrastructure:** Encourage the provision of readily accessible and well-maintained tyre inflation stations at fuel stations or public service points to facilitate easy and accurate tyre pressure maintenance for all drivers.

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