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COMPARATIVE ANALYSIS OF NEW AND USED TYRES: TYRE LIFE, TREAD DEPTH, AND ENVIRONMENTAL IMPACT

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Abstract
Comparative analysis of new and fairly used tyres is important for evaluating their performance, safety, cost-effectiveness, and environmental impact and to undertake research and development in tyre technology. This study presents a comparative analysis of new and used tyres, focusing on their lifespan, tread depth, and environmental impact. Mathematical models were developed to predict tyre lifespan and environmental impact. Experimental tests were also conducted on several tyre brands available in Nigeria to assess changes in hardness, tensile strength, and impact strength over time. The average values of hardness obtained during the hardness tests for the new tyres for samples A, B, C, D, and E are 66, 70, 68, 60, and 76 and for the fairly used tyres of the same samples for 1, 2, 3, 4, 5, and 6 years are 79.5, 77, 71.7, 69.2, and 80 respectively. The tensile stresses also obtained range from 7.80 to 8.20 N/mm^2. The stresses obtained at 100% and 200% range from 2.77-2.83 N/ mm^2 and 5.90 – 5.99 N/mm^2, respectively. The strain at break was within 233 to 247%. Results show a decline in the mechanical properties with increased usage, and the models suggest that the tread depth significantly influences the performance, safety, and fuel efficiency.

1. Introduction

Tyres are designed for durability and contain a complex mix of materials, including natural and synthetic rubber, carbon black, steel, and chemical additives. Their composition makes them resistant to biodegradation, with decomposition times extending to hundreds of years [1]. The comparison between new and used (or part-worn) tyres encompasses several critical factors, including performance, safety, cost-effectiveness, and environmental impact. While new tyres offer optimal performance and safety assurances, used tyres provide a cost-effective alternative with certain trade-offs. Worldwide, researchers in the field of tyre technology have spent a lot of energy on the comparative analysis of new and used tyres, models and parameters. Notable contributions to this field include Liu et al. [2], who investigated the trade-offs between new and used (part-worn) tyres, focusing on

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cost-effectiveness, performance characteristics, and safety implications. Singh et al. [3] also evaluated the environmental impact of new and used tyres through life cycle assessment (LCA), focusing on material consumption, energy usage, and waste generation. The research infers that used tyres offer short-term environmental benefits by reducing manufacturing impacts but face challenges related to waste disposal and frequent replacement cycles. In contrast, new tyres result in higher initial emissions but perform better in terms of durability and long-term sustainability. Mishra et al. [4] presented a comparative study of new and used tyres for passenger cars. The study found that the new tyres offer superior performance, safety, and durability compared to the used tyres. While used tyres may be a cost-effective option, their reduced performance and increased safety risks make them a less desirable choice for passenger cars. Kumar [5] evaluated the safety and performance characteristics of used tyres compared with those of new tyres, focusing on their braking efficiency, handling stability, and durability under varied driving conditions. The study highlights that while used tyres are economically viable, they exhibit compromised safety and performance, particularly under wet and high-stress conditions. Careful monitoring of the tread depth and structural integrity is essential to ensure road safety. Rajput and Kumar [6] also presented a comparative analysis of new and retreaded truck tyres. The study found that while new tyres offer superior performance and durability, retreaded tyres can be a viable option for truck owners, providing a cost-effective and environmentally friendly solution. However, retreaded tyres may require more frequent maintenance and inspections to ensure safety and performance. El-Fahham et al. [7] analyzed the strength of vehicle tyres through a series of experiments and simulations. This study investigated the effects of various factors, including inflation pressure, load, and speed, on the tyre's strength and performance. The study also developed a mathematical model to predict the tyre's strength and performance under various conditions. Kumar et al. [8] examined the **s**afety and performance characteristics of used tyres compared with those of new tyres, focusing on parameters such as tread depth, traction, braking efficiency, and structural durability under diverse driving conditions. Awasthi and Singh [9] also presented a comparative analysis of new and used tyres for electric vehicles (EVs). The study found that while used tyres may be a cost-effective option, their reduced performance and increased safety risks make them a less desirable choice for EVs. A study by Gao and Chen [10] investigated the effect of tyre inflation pressure on tread wear rates and patterns, analyzing how over-inflation and under-inflation impact tyre durability, safety, and performance. The study deduced that improper inflation pressure significantly affects tread wear, performance, and safety. Jones et al. [11] also examined the relationship between driving styles and tyre lifespan, focusing on how aggressive driving behaviour impact tread wear, performance degradation and replacement frequency. The study found that aggressive driving accelerates wear and tear, while smooth driving promotes durability, fuel efficiency, and lower replacement rates. Kumar and Saini [12] studied the impact of environmental factors such as temperature, UV radiation, humidity, and ozone exposure on tyre aging, performance degradation, and safety risks. The research emphasizes the need for climate-specific designs, protective coatings, and proper storage practices to mitigate these effects. Li and Wang [13] explored the mechanisms of oxidative degradation in tyre rubber materials and proposed mitigation strategies to enhance durability and performance under oxidative stress. The study also concluded that oxidative degradation is a major factor in the aging and performance decline of tyre rubber materials. Rao and Stevenson [14] investigated the influence of road surface conditions on tyre wear rates, focusing on how the texture, roughness, and material composition of pavements affect tread degradation, performance, and safety. Richard [15] also analyzed tyre usage and failure rates among drivers in Ondo, Nigeria. This study highlighted the prevalence of used tyres and their contribution to road accidents, emphasizing the need for better maintenance and awareness. Zhang et al. [16] presented a comparative study of new and used tyres for passenger cars under different road conditions. The study emphasized the importance of using high-quality, properly maintained tyres to ensure optimal vehicle performance and safety. Iribhogbe [17] explored the conversion of used tyres into bio-crude oil via pyrolysis. This study examined the characteristics and composition of the produced oil, highlighting its potential applications and environmental benefits. Liu et al. [18] evaluated the cost**,** performance, and safety of new and used tyres to determine their suitability for various driving conditions and economic viability. Liu et al. [19] also presented a comparative analysis of new and used tyres, focusing on their safety**,** performance, and environmental impact to evaluate their suitability for different applications. A study by Al-Khateeb et al. [20] examined the mechanical properties of used tyres to assess their structural integrity, durability, and performance characteristics after prolonged use. It also evaluates their suitability for reuse and recycling applications. The study found that used tyres experience significant mechanical degradation over time, affecting their performance and safety for road use. However, they remain valuable resources for recycling and re-purposing in non-automotive applications. Lee et al. [21] evaluated the performance of used tyres under different road conditions. This study conducted experiments on used tyres with varying tread depths and tested them on different road surfaces, including dry, wet, and rough roads. The study highlighted the importance of proper tyre maintenance and replacement to ensure road safety, particularly for vehicles using used tyres. Patel et al. [22] assessed the environmental impact of used tyres, focusing on their disposal, recycling, and reuse. The study stated the need for sustainable management practices for used tyres to mitigate their environmental impact and promote a circular economy. Muller and Blundell [23] investigated the performance of tyres used with road-rail vehicles (RRVs). This study measured the braking force as a function of the tyre slip ratio for a range of conditions relevant to the performance of RRVs during typical operations when on a rail track. The study found that the friction coefficient estimated from the tests was approximately 50% of those obtained on the road in both wet and dry conditions. Hu et al [24] investigated the vertical mechanical properties of tyres, focusing on their hysteresis-rolling characteristics. The researchers validated their theoretical model using experimental data and found good agreement between the predicted and measured results. This study provides new insights into the vertical mechanical properties of tyres and can be used to improve tyre design and simulation models. Overall, the study contributes to the understanding of tyre behavior and can be applied to improve vehicle safety, handling, and performance. Liu and Gao [25] presented an analytical investigation of tyre dynamics using a rigid-elastic coupled tyre model with nonlinear sidewall stiffness. The researchers developed a mathematical model that considers the nonlinear behavior of the tyre's sidewall and its effects on the tyre's dynamic behavior. El-Fahham et al. [26] assessed the environmental impact of new and used tyres. The study found that both new and used tyres have significant environmental impacts. However, the impacts vary across different life cycle phases. Barinov et al. [27] evaluated the challenges associated with global tyre waste management and proposed sustainable solutions for handling end-of-life tyres (ELTs) to minimize the environmental impact and promote resource recovery. The study emphasizes that global tyre waste management requires integrated strategies combining recycling technologies**,** energy recovery methods, and eco-friendly manufacturing to tackle waste challenges effectively. It highlights the need for policy reforms**,** industry collaboration, and sustainable practices to create a circular economy **for** end-of-life tyres. This review synthesizes findings from various studies and sources to provide a comprehensive analysis of new and used tyres.

2.0 METHODOLOGY

This review synthesizes findings from research papers, industry reports, and technical standards to provide an overview of the comparative analysis of new and used tyres, focusing on tyre life, tread depth, and environmental impact. The study also develops mathematical models to predict the lifespan, effect of tread depth and environmental impact of used tyres. Standard tests are conducted to investigate the mechanical properties such as the hardness, tensile strength and impact strength of different specimens of new and fairly used tyres available in Nigeria.

2.1 TYRE LIFE

The lifespan of tyres is influenced by a combination of intrinsic properties and external environmental, operational, and maintenance factors. Several studies and reviews in the literature have addressed these aspects, contributing to a comprehensive understanding of tyre wear and degradation mechanisms. Optimizing tyre lifespan involves purchasing high-quality tires, adhering to proper maintenance practices, adjusting driving habits, and monitoring environmental exposure. Addressing these factors can maximize safety and reduce the costs associated with premature tire replacement. To model the lifespan of fairly used tyres mathematically, we need to consider various factors that affect tyre wear and degradation. These factors include mileage, load, road conditions, inflation pressure, weather conditions, and maintenance practices [28]. The tyre lifespan, T, can be approximated as

$$T = \frac{T_0}{W\, f\,(M,L,P,R,E,C)} \quad (1)$$

Where T_0, W, M, L, P, R, E and C are the initial tread depth (mm), total mileage driven (km or time e.g., months/year), rate of wear per unit distance (mm/km or percentage/km), average load on the tyre (kg), inflation pressure (bar), road condition factor (dimensionless, e.g., 1 for good roads, >1for rough roads), environmental factor (e.g., average temperature, UV exposure, weather conditions) and maintenance factor (e.g., rotation frequency, balancing, alignment), respectively. $f\,(M, L, P, R, E, C)$ is a function that models the combined effect of all factors on the wear rate. Equation 2 also represents the wear rate, W

$$W = W_0\,(1 + \alpha_1 \frac{L}{L_{max}} + \alpha_2 \frac{P - P_{opt}}{P_{opt}} + \alpha_3 R + \alpha_4 E - \alpha_5 C) \quad (2)$$

Where W_0 , α_1 , L_{max} and P_{opt} are the baseline wear rate, weight coefficients for each factor, maximum allowable load and optimal inflation pressure, respectively.

Similarly, the mileage-based lifespan, assuming linear wear, is expressed in equation (3).

$$T = \frac{T_0}{W.M} \quad (3)$$

Where M represents the mileage until the tyre reaches the minimum allowable tread depth. The environmental conditions that cause degradation over time can be modeled as in equation (4):

$$D = \beta_1 E \cdot t + \beta_2 \quad (4)$$

Where D, t, $\beta_1$and β_2 are the degradation factors (e.g., rubber, oxidation), time (in year), and constants based on environmental factors.

Thus, the lifespan considering degradation becomes

$$T = \min.\,(\frac{T_0}{W.M}\,.\,T_0) \quad (5)$$

Maintenance also improves the lifespan by reducing wear and degradation; hence, the lifespan can be modeled as in equation (6) considering the impact of maintenance.

$$T = T_{baseline} \cdot (1+\gamma C) \quad (6)$$

Where γ is a proportionality constant for the maintenance benefits. These equations 1-6 can be refined with empirical data specific to the tyres, usage conditions, and environmental exposure to provide more accurate predictions.

2.2 Tread Depth and Its Impact on New and Used Tyres

Tread depth plays a critical role in determining the performance, safety, and lifespan of both new and used tires. It influences the tyre's ability to grip the road, handle water on the surface, and resist wear. The difference in tread depth between the new and used tires significantly affects their performance under various conditions. Tread depth is a crucial determinant of tire performance, with new tires offering superior grip, durability, and safety. While used tires can be cost-effective, their reduced tread depth necessitates careful monitoring and earlier replacement to avoid compromising safety and handling. New tires typically come with a full tread depth of 8–10 mm, depending on the type and intended use (e.g., passenger car tires, off-road tires) [29-30]. The deeper tread provides a performance and safety advantage, making them suitable for various driving conditions and longer-term use. Drivers should frequently check tread depth and replace tyres before reaching the legal minimum to maintain safety [31-32]. Additionally, used tires are less reliable in adverse weather conditions, such as heavy rain or snow. Table 1 shows the comparison between the new and used tyres.

Table 1: Comparison between new and used tyres

Factor	New Tyres	Used Tyres
Tread Depth	Full depth (8 – 10 mm)	Reduced depth (< 8 mm, often < 5 mm)
Traction	High on all surfaces	Reduced, especially on wet/slippery roads
Water Handling	Excellent (efficient water channeling)	Decreased; prone to hydroplaning
Wear Resistance	Longer lifespan with slower wear rate	Shorter lifespan with faster wear rate
Damage Resistance	Higher due to thicker tread layer	Lower; prone to punctures and cracks

The influence of tread depth on used tyres can be modeled mathematically by considering how tread wear impacts various factors such as tyre performance, fuel efficiency, safety, and environmental impact. The tread depth decreases over time due to use, and as the depth reduces, the performance characteristics change. As the tyre is used, the tread depth decreases. The rate of tread wear can be modeled using a simple linear or nonlinear decay model depending on the usage conditions. A simple linear decay model is:

$$T_c(t) = T_i - \alpha \cdot t \qquad (7)$$

Where T_c, T_i, α and t are the current tread depth (mm), initial tread depth of the tyre, which decreases over time (mm) and time of usage, respectively.

Alternatively, if the wear is not linear (e.g., because of variations in driving conditions), a nonlinear model can be used:

$$T_c(t) = T_i - \beta t^n \qquad (8)$$

Where β and n are constants related to the wear intensity and an exponential that dictates the nonlinearity of the tread wear, respectively.

As the tread depth decreases, the safety of the tyre reduces, especially in wet conditions, because there is less ability to channel water away from the tyre surface. The safety factor can be modeled as a decreasing function of the tread depth as in Eq. (9).

$$S = K.T_c \qquad (9)$$

Where K is a constant that adjusts the impact of the tread depth on safety. The safety factor decreased as the tread depth decreased.

Alternatively, for a more nonlinear relationship:

$$S = K.(T_c)^m \qquad (10)$$

Where m is an exponent that determines how quickly safety degrades with wear.

Tread depth can also affect the fuel efficiency. A greater tread depth generally results in more rolling resistance, which negatively affects the fuel economy. As the tread wears down, the rolling resistance reduces, which may improve the fuel efficiency. We can model fuel efficiency as a function of the remaining tread depth:

$$F_f = F_i \{1- \gamma. (T_i - T_c)\} \quad (11)$$

Where F_i and γ are the initial fuel efficiency (when the tyre is new) and the constant that quantifies the change in fuel efficiency per unit of tread wear, respectively. Alternatively, a simple linear relationship might be:

$$F_f = F_i \left(1- \delta. \frac{T_i - T_c}{T_i}\right) \quad (12)$$

Where δ is a constant that quantifies the decrease in fuel efficiency as the tread wears down.

The performance of the tyre (including handling, traction, and braking) also deteriorates as the tread depth decreases. A simple model for performance might be:

$$P_p = P_i \left(\frac{T_c}{T_i}\right)^n \quad (13)$$

Where P_i and n are the initial performance of the tyre and an exponent that dictates how quickly the performance deteriorates with decreasing tread depth.

2.3 Environmental Challenges of the Used Tyres

The environmental impact of the used tyres is significant due to their durability, non-biodegradability, and potential for pollution. Effective management strategies, including recycling, re-treading, and innovative reuse, are essential to mitigate these impacts. Collaborative efforts between governments, manufacturers, and consumers are key to creating a sustainable lifecycle for tires, reducing their environmental footprint, and minimizing associated risks. The environmental impact can be considered in terms of the tyre's effectiveness in reducing rolling resistance and its eventual disposal. Used tires occupy significant landfill space and create long-term environmental hazards. Their hollow, non-compressible structure trap air and water, causing them to rise to the surface of landfills, disrupting operations [33-34]. Additionally, the space they occupy could otherwise be used for biodegradable waste, worsening landfill overcrowding. Tires are highly flammable, and once ignited, fires are difficult to extinguish due to their high energy content. Tyre fires release hazardous pollutants, including carbon monoxide, sulfur oxides, and volatile organic compounds (VOCs). The long-term smoldering of tire piles has been documented to release carcinogenic compounds, such as polycyclic aromatic hydrocarbons (PAHs) [35]. The environmental impact of tyre fires includes air pollution, soil contamination, and water pollution from runoff. Tires contain heavy metals, such as zinc, lead, and cadmium, as well as other toxic compounds [36-37]. When disposed of improperly or exposed to environmental elements, these chemicals leach into the soil and groundwater. Research by Wik and Dave [38] found that leachates from tyres can be toxic to aquatic ecosystems, reducing biodiversity and altering water quality. Wear and tear during tire use generate tire wear particles (TWP), which are a major source of micro plastic pollution. According to Kole et al. [39], TWP accounts for approximately 30% of all micro plastics in the environment. These particles are transported into waterways and oceans, where they pose risks to aquatic organisms through ingestion and chemical exposure. Discarded tires often collect stagnant water, creating ideal conditions for mosquito breeding. This contributes to the spread of mosquito-borne diseases, such as malaria, dengue, and Zika virus, particularly in tropical and subtropical regions [40]. Landfilling remains one of the most common methods for tire disposal, but it poses significant long-term environmental risks, including the potential for chemical leaching and fire hazards [41]. Tyres are often incinerated for energy recovery in cement kilns and power plants. While this reduces landfill use, it releases greenhouse gases (GHGs), such as carbon dioxide, and other harmful pollutants, including dioxins and furans [42-43]. Studies by Williams [44] highlight the trade-offs between energy recovery and air quality impacts.

Inadequate disposal facilities and enforcement have led to the widespread illegal dumping of tires. These dumps pose fire risks, serve as disease vectors, and degrade the esthetic value of landscapes [45-46]. To create a mathematical model for the environmental impact of used tyres, we need to focus on several factors that contribute to the environmental impact. These factors can include waste generation, pollution, resource use, and the degradation or recycling process of the tyres. A general approach would be to break the environmental impact down into components, like the emission of pollutants, energy consumption, and waste reduction. The waste generation, w_g can be represented by the number of used tyres that need to be disposed of or recycled. Thus:

$$w_g = T_{disposed} = T_{total} - T_{recycled} \quad (14)$$

Where $T_{disposed}$, T_{total} and $T_{recycled}$ are the total number of tyres used in a given period, the number of tyres that were successfully recycled and the number of tyres disposed of in landfills or through incineration. The environmental impact, I_f (in terms of fuel consumption) over the usage period can be represented by

$$I_f(t) = \int_0^t F_f \{T_c(t)\}\, dt \quad (15)$$

As the tread wears, the fuel efficiency changes, so these integral captures the change in the environmental impact over time. Used tyres also contribute to air and water pollution through various mechanisms, such as burning (emitting CO_2 and particulate matter) and leaching of toxic substances into the environment. The total pollution can be represented as

$$P = E_{CO_2} + E_{toxic} = aT_{disposed} + bT_{disposed} \quad (16)$$

Where E_{CO_2}, E_{toxic} , a and b are the carbon dioxide emissions from burning used tyres, emissions of toxic substances (e.g., heavy metals, PAHs) and constants based on the type of tyre material and disposal method, respectively.

The recycling of tyres requires energy, but it also reduces the environmental impact by decreasing the need for raw material extraction and reducing the number of tyres sent to landfills. The total energy consumption in recycling, R_C is:

$$R_C = E_{recycling} . T_{recycled} \quad (17)$$

Where $E_{recycling}$ and $T_{recycling}$ are the energy consumed in recycling one tyre and the number of tyres recycled. Recycling tyres has the benefit of reducing the need for raw materials and avoiding emissions from new material production. The total environmental benefit can be expressed as

$$B_e = (E_{saved} . T_{recycled}) + (C_{saved} . T_{recycled}) \quad (18)$$

Where E_{saved} and C_{saved} are the amounts of energy saved by recycling and carbon dioxide saved by recycling, respectively. The total environmental impact can be represented as a combination of the pollution, waste generation, energy consumption, and environmental benefits of recycling. Thus, the total environmental impact is:

$$I_e = w_g + I_f + P + R_c + B_e \quad (19)$$

2.4 Tests

All tests were carried out using calibrated equipment, and the test procedures were performed according to international standards. Samples were prepared accordingly from some new and fairly used tyre products available in Nigeria namely; Bridgestone, Pirrelli, Dunlop, Firestone and Goodyear. Some of the mechanical properties of the specimens were determined using a universal tensile testing machine for the tensile test, Izod for the impact test, and a Vickers hardness apparatus for the hardness testing. Table 2 shows sample preparation's parameters and specifications.

Table 2: Sample preparation parameters and specifications

S/N	Parameters	Specifications
1	Sample	Vulcanized rubber
2	Test piece shape	Dumb-bell shape
3	Testing temperature	Room temperature

4	Load method	Crosshead movement
5	Measurement conditions	Direct measurement of the test force

The following steps were followed during testing:

- Sample selection: Six samples were selected from the following tyre products available in Nigeria namely; Bridgstone, Pirrelli, Dunlop, Firestone, Michelin and Goodyear.
- Sample preparation: Six pieces' test piece shapes were prepared accordingly in accordance with the method used by National Highway Traffic Safety Administration, NHTSA (47). The width of the parallel part was 5 mm, dumbbell shape, about 100 mm total length and 20 mm distance between the guage.
- Test setup: This step is very crucial during the test of the material. the equipment must be setup to be compatible with the test to be carried out. Three important considerations necessary for the effective performance of the testing machine include the control of the test speed, load or strain rate as required by the test specification; the force capacity sufficient to break the specimens to be tested; and the accuracy and precision sufficient to obtain and properly record the load and extension information generated by the test.
- Test procedure: The test procedure followed is similar to that used by the NHTSA tyre aging development project. Strain was directly measured using an extensometer, and the distance between the gauge marks was also measured up to the point of breaking in real time.

3.0 RESULTS AND DISCUSSION

Figure 1 depicts the comparison between the lifespan of new and used tyres using tread depth and mileage. The graph compares the lifespan of a new tire to that of fairly used tires aged 1 to 5 years before purchase. The new tyre starts with a full tread depth (8 mm) and has a longer lifespan due to a lower wear rate. Each additional year of prior use reduces the lifespan due to the increased wear rate caused by age-related degradation. The reduction in lifespan is more pronounced as the age increases. This illustrates how usage and age impact the lifespan of tires

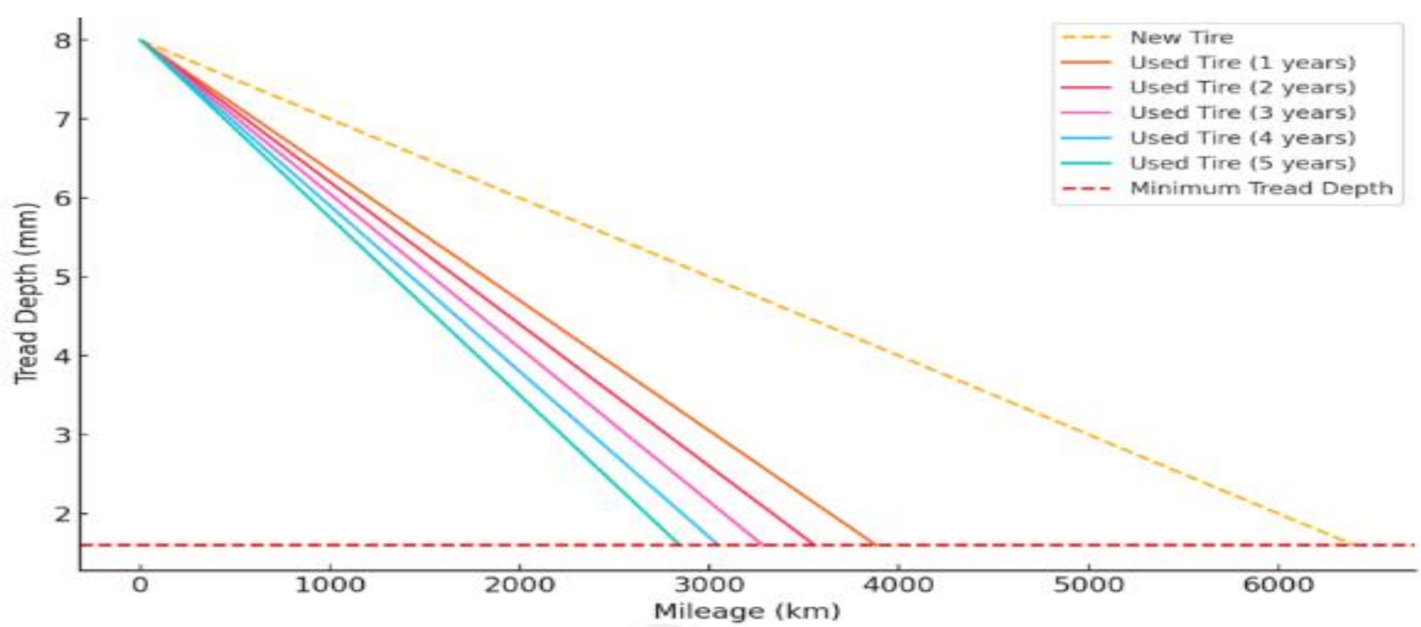

Figure 1: Tyre Lifespan Comparison between New and Used Tyres

The test results of the of hardness on shore A durometer scale per ASTM standard in the laboratory are also depicted in Figure 2 and Table 3. The results depicted the average shore hardness for the tyre treads versus the age of the tyres. It shows the average shore A hardness of the treads for the fire tyre models. The results depicted a inear

S/N	SAMPLE								
1	A (Bridgestone)	AGE	0	1	2	3	4	5	6
		SHORE HARDNESS	66	72	75	77	81	86	86
2	B (Pirreli)	AGE	0	1	2	3	4	5	6
		SHORE HARDNESS	70	75	75	77	77	79	79
3	C (Dunlop)	AGE	0	1	2	3	4	5	6
		SHORE HARDNESS	68	68	70	70	72	75	75
4	D (Firestone)	AGE	0	1	2	3	4	5	6
		SHORE HARDNESS	60	65	65	70	70	70	75
5	E (Goodyear)	AGE	0	1	2	3	4	5	6
		SHORE HARDNESS	76	76	80	80	80	82	82

increase in the tread hardness with the Age of the tyre. It was found that the hardness ranged from 68 for new tyres and 82 for fairly used tyres.

Table 3: Test results of the hardness on shore A durometer for different tyre product names

S/N	SAMPLE								
1	A (Bridgestone)	AGE	0	1	2	3	4	5	6
		SHORE HARDNESS	66	72	75	77	81	86	86
2	B (Pirreli)	AGE	0	1	2	3	4	5	6
		SHORE HARDNESS	70	75	75	77	77	79	79
3	C (Dunlop)	AGE	0	1	2	3	4	5	6
		SHORE HARDNESS	68	68	70	70	72	75	75
4	D (Firestone)	AGE	0	1	2	3	4	5	6
		SHORE HARDNESS	60	65	65	70	70	70	75
5	E (Goodyear)	AGE	0	1	2	3	4	5	6
		SHORE HARDNESS	76	76	80	80	80	82	82

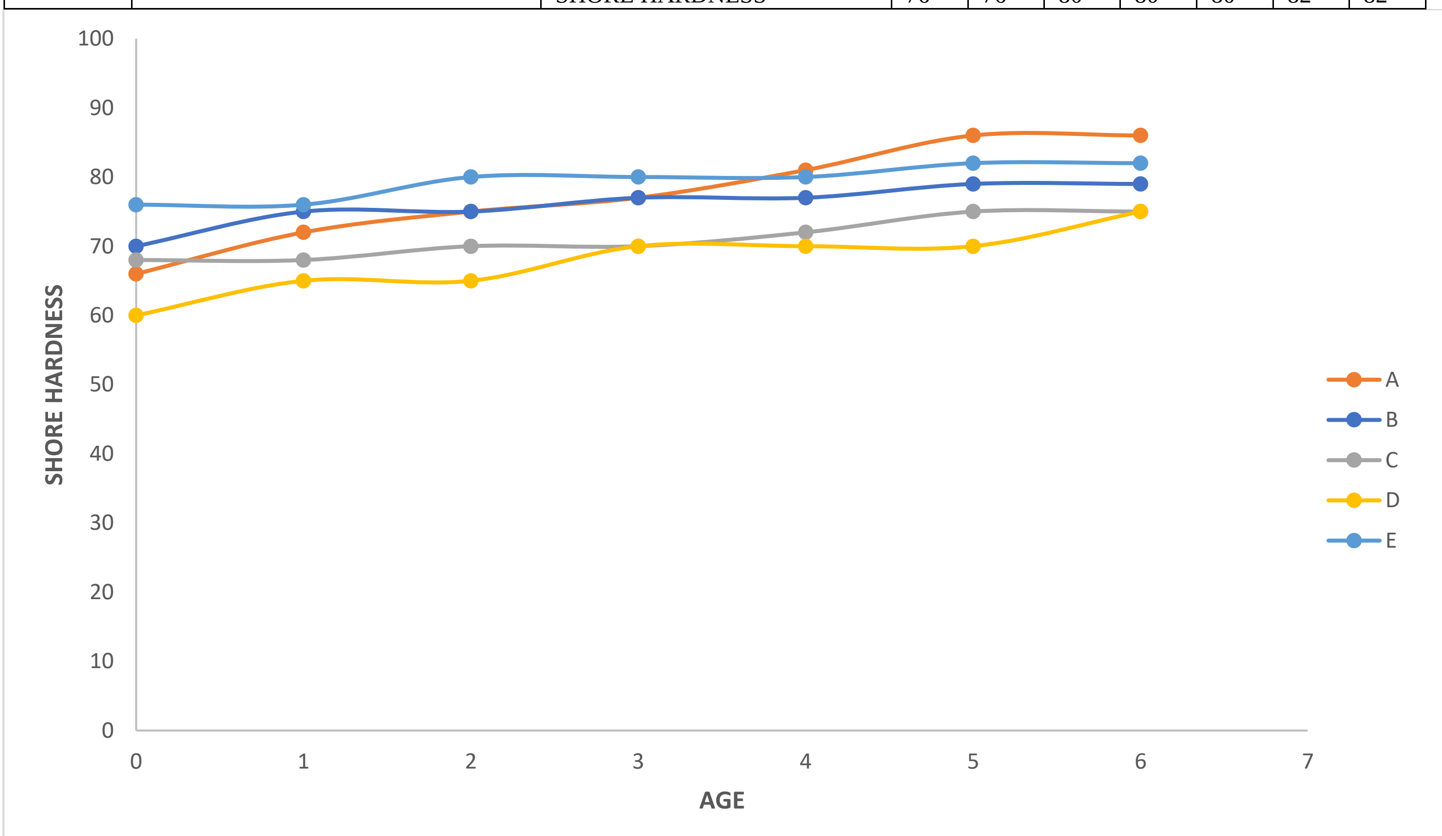

Figure 2: Plot of shore hardness against age of the different tyre samples used

Table 4 depicts the results obtained during the tensile test of different new product names used in Nigeria. The tensile stresses obtained range from 7.80 to 8.20 N/mm^2. The stresses obtained at 100% and 200% range from 2.77-2.83 N/ mm^2 and 5.90 – 5.99 N/mm^2, respectively. And the strain at break is within 233 to 247%.

Table 4: Results of the Tensile Test of Different Tyre Products (0 Year)

Tyre Products	Tensile Strength (N/mm^2)	Stress at 100% Strain (N/mm^2)	Stress at 200% Strain (N/mm^2)	Strain at Break (%)
Bridgestone	8.20	2.79	5.90	239
Pirreli	7.10	2.83	5.93	245
Dunlop	8.10	2.81	5.98	237
Firestone	7.80	2.77	5.99	247
Goodyear	7.90	2.82	5.96	233

The results obtained for used tyre products considered with usage of 1, 2, 3, 4, 5, and 6 years are depicted in Tables 5-10. It shows that the mechanical properties of the tyres decrease with time of usage.

Table 5: Tensile Test Results Obtained for Different Samples of Tyre Products (1 Year)

Tyre Products	Tensile Strength (N/mm^2)	Stress at 100% Strain (N/mm^2)	Stress at 200% Strain (N/mm^2)	Strain at Break (%)
Bridgestone	7.20	2.59	5.10	215
Pirreli	6.90	2.65	5.15	205
Dunlop	7.90	2.71	5.00	210
Firestone	7.40	2.66	5.05	200
Goodyear	7.60	2.83	4.90	210

Table 6: Tensile Test Results Obtained for Different Samples of Tyre Products (2 Years)

Tyre Products	Tensile Strength (N/mm^2)	Stress at 100% Strain (N/mm^2)	Stress at 200% Strain (N/mm^2)	Strain at Break (%)
Bridgestone	7.10	2.65	4.90	200
Pirreli	6.70	2.70	4.95	195
Dunlop	7.70	2.69	4.85	188
Firestone	7.20	2.78	4.60	190
Goodyear	7.30	2.55	4.75	199

Table 7: Tensile Test Results Obtained for Different Samples of Tyre Products (3Years)

Tyre Products	Tensile Strength (N/mm^2)	Stress at 100% Strain (N/mm^2)	Stress at 200% Strain (N/mm^2)	Strain at Break (%)
Bridgestone	6.90	2.49	4. 50	195
Pirreli	6.50	2.55	4.55	185
Dunlop	7.50	2.40	4.35	179
Firestone	7.20	2.30	4.45	180
Goodyear			4.25	185

	7.10	2.35		

Table 8: Tensile Test Results Obtained for Different Samples of Tyre Products (4 Years)

Tyre Products	Tensile Strength (N/mm^2)	Stress at 100% Strain (N/mm^2)	Stress at 200% Strain (N/mm^2)	Strain at Break (%)
Bridgestone	6.80	2.10	4.20	185
Pirreli	6.40	2.45	4.15	177
Dunlop	7.30	2.32	4.20	170
Firestone	7.00	2.25	4.10	175
Goodyear	6.90	2.11	4.15	180

Table 9: Tensile Test Results Obtained for Different Samples of Tyre Products (5 Years)

Tyre Products	Tensile Strength (N/mm^2)	Stress at 100% Strain (N/mm^2)	Stress at 200% Strain (N/mm^2)	Strain at Break (%) (N/mm^2)
Bridgestone	6.40	2.44	4.05	170
Pirreli	6.20	2.29	4.00	170
Dunlop	7.10	2.24	4.10	165
Firestone	6.80	2.45	4.00	170
Goodyear	6.50	2.35	4.00	175

Table 10: Tensile Test Results Obtained for Different Samples of Tyre Products (6 Years)

Tyre Products	Tensile Strength (N/mm^2)	Stress at 100% Strain (N/mm^2)	Stress at 200% Strain (N/mm^2)	Strain at Break (%)
Bridgestone	6.10	2.19	4.00	160
Pirreli	5.90	2.12	3.95	165
Dunlop	7.00	2.22	4.00	160
Firestone	6.50	2.34	3.85	165
Goodyear	6.20	2.14	3.95	160

4.0 CONCLUSSION

The lifespan of a tyre is determined by a complex interplay of material properties, operational conditions, maintenance practices, and environmental factors. Advances in tyre design, such as the use of nanocomposites and wear-resistant compounds, offer the potential for extending tire lifespan. Used tyres pose multifaceted environmental challenges, including landfill overcrowding, pollution, and health risks. However, advancements in recycling, innovative repurposing, and stricter regulatory frameworks offer viable solutions. The results obtained from the tests also provided data that can be used to support the development of a new empirical tyre model to allow the design of simulation and optimization of future reused of fairly used pneumatics tyres.

Collaborative efforts among governments, industries, and researchers are essential to minimize the environmental footprint of used tyres and transition toward a more sustainable tyre lifecycle. Future research should focus on the predictive modeling of tyre wear under diverse conditions and the development of sustainable tyre materials.

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