Engineering Assessment of Passenger and Payload Overloading Using Gross Vehicle Weight Rating Compliance: Evidence from Edo North Senatorial District, Nigeria

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Abstract: Passenger and payload overloading remain major contributors to road traffic crashes, accelerated pavement deterioration, increased vehicle operating costs, and reduced transportation efficiency in many developing countries. Despite existing regulations, persistent non-compliance with manufacturers' Gross Vehicle Weight Rating (GVWR) continues to compromise road safety and infrastructure sustainability in Nigeria. This study presents an engineering assessment of passenger and payload overloading among commercial public transportation vehicles operating within Edo North Senatorial District, Nigeria. The study was a 12 month field survey of 500 commercial vehicles at 10 major interstate transport terminals. The vehicles were divided into four groups: Toyota Hiace buses, Toyota Sienna vehicles, Toyota Sharon vehicles and Peugeot 504 Station Wagons. Gross Vehicle Weight (GVW) was calculated from the measured curb weight, passenger load, driver weight, cargo load and fuel weight, and compared to the manufacturer's GVWR to evaluate vehicle load compliance. Loading characteristics were summarized using descriptive statistics, and an exploratory one-way Analysis of Variance (ANOVA) was conducted on the monthly cargo loading data to compare the loading patterns across vehicle categories. The results showed that the highest passenger overloading was 42.9% in Toyota Sharon vehicles followed by Toyota Sienna and Peugeot 504 Station Wagon vehicles 25.0%, while Toyota Hiace buses had the highest annual average cargo load of 151.3 kg. Cargo loading increased in January, November and December, due to seasonal travel demand. The ANOVA test showed a significant difference in the mean of cargo loading among the vehicle categories studied with F (3, 44) = 4.48, and p = 0.0079. Thus, the type of vehicle significantly affects the characteristics of cargo-loading. The results also show that the main reason for Gross Vehicle Weight violations is passenger overloading and the cargo loading is within the estimated manufacturer payload capacities of the vehicles considered. The study shows that better regulatory enforcement, routine monitoring of gross vehicle weight and deployment of intelligent weigh-in-motion technologies would improve compliance with vehicle loading, enhance road safety and promote sustainable public transportation in Nigeria.

Keywords: *Passenger Overloading; Payload Overloading; Gross Vehicle Weight Rating (GVWR); Gross Vehicle Weight (GVW); Commercial Transportation; Road Safety; Vehicle Load Compliance; Edo North Senatorial District.*

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I. INTRODUCTION

Introduction Road transportation is the major mode of passenger and freight movement in Nigeria and it is vital to economic growth, regional integration and social development [1]. Its availability and the relatively low requirements of capital have made it the preferred means of mobility. However, the increasing demand for commercial transport has aggravated the overloading of passengers and payload, which impacts vehicle safety, transport efficiency and highway infrastructure. Excessive vehicle loading remains a persistent challenge in many developing countries where enforcement of loading regulations is inadequate [2]–[3].

Road traffic injuries remain a major global public health concern. According to the World Health Organization, road traffic crashes cause an estimated 1.19 million deaths

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per year. More than 90% of these deaths occur in low- and middle-income countries [4]. A significant contributing factor is the overloading of vehicles when the gross vehicle weight (GVW) exceeds the gross vehicle weight rating (GVWR) set by the vehicle manufacturer. It increases braking distance, reduces the steering response, overstresses the suspension and tyre systems, increases the rollover risk and accelerates the structural fatigue of vehicle components [5]–[6].

Overloading not only raises safety concerns but also leads to pavement deterioration due to the excessive axle loads, which cause fatigue cracking, rutting, premature pavement failure, and increased maintenance costs [7]. Also, overloading of vehicles increases fuel consumption, greenhouse gas emissions and wear of tyres, braking systems, suspension components and driveline assemblies, making it a significant transportation safety, pavement management, economic and environmental sustainability challenge [8], [9].

Technological advances such as weigh-in-motion (WIM) systems, Internet of Things (IoT)-based sensors, artificial intelligence (AI), and automated enforcement technologies have greatly improved vehicle load monitoring, overload detection and regulatory compliance in many developed countries [10]–[11]. However, these technologies are still not widely used in Nigeria, where the enforcement of vehicle loading is still largely based on manual inspection and periodic roadside operations [12].

In Nigeria, operators are encouraged to exceed approved passenger and payload limits due to increasing transport costs, inadequate fleet capacity, weak regulatory enforcement and rising passenger demand [2] . Although Toyota Hiace, Toyota Sienna, Toyota Sharon, and Peugeot 504 Station Wagon vehicles dominate interstate commercial transportation, few engineering studies have quantitatively evaluated their compliance with manufacturers' Gross Vehicle Weight Rating (GVWR) under actual operating conditions or examined the combined effects of passenger occupancy and payload on vehicle performance [13].

Edo North Senatorial District is a major transportation corridor connecting southern and northern Nigeria through interstate routes serving Abuja, Benin City, Warri, Onitsha, Kaduna, Ibadan, Ilorin, and neighbouring cities. Despite its strategic importance and high traffic volume, limited evidence exists on passenger and payload overloading, GVWR compliance, and the associated engineering implications for vehicle performance, road safety, and pavement deterioration.

This study therefore evaluates passenger and payload overloading in selected commercial public transportation vehicles operating within Edo North Senatorial District by comparing measured GVW with manufacturers' GVWR. It measures compliance with vehicle loading limits, investigates the influence of passenger occupancy and cargo loading on overloading and produces engineering data to support improved loading management, enhanced enforcement of regulations and implementation of intelligent monitoring technologies for safer and more sustainable public transport systems.

II. MATERIALS AND METHOD

- *Study Area*

The study was located in Edo North Senatorial District, Edo State, Nigeria, which is a major transportation corridor between southern and northern Nigeria by interstate highways. The district is noted for intensive commercial passenger transportation because of its strategic location along the Benin – Abuja corridor. Data were collected from ten major interstate passenger terminals designated as R1–R10 to preserve commercial confidentiality and to ensure unbiased analysis. To account for the seasonal variation in passenger and cargo loading a survey of twelve months duration was carried out covering normal and festive travel periods.

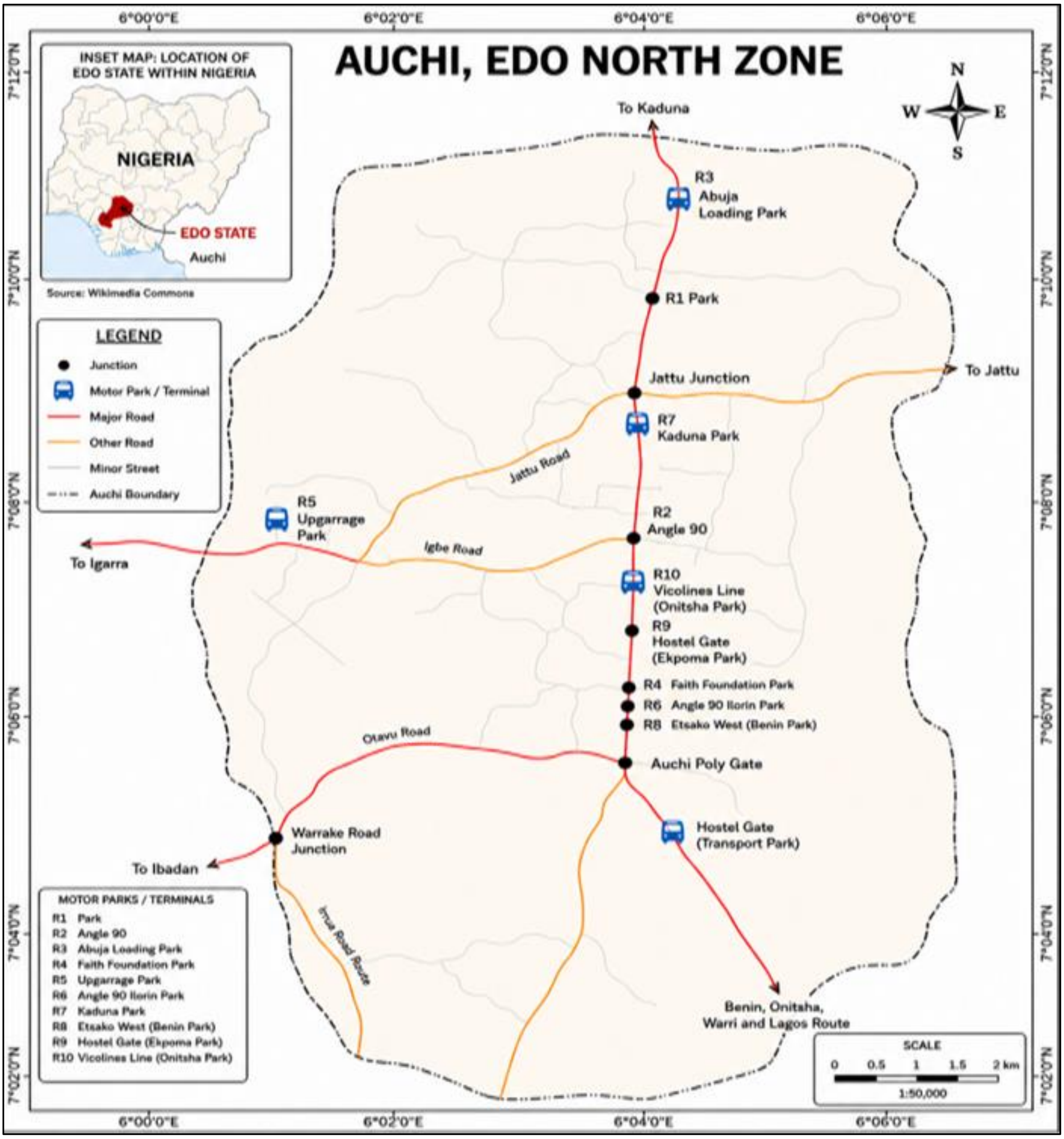

Fig 1 Map of Edo North Senatorial District Showing the Locations of the Sampled Transport Terminals (R1–R10).

➢ *Research Design*

A cross-sectional field survey was conducted to evaluate passenger and payload loading in commercial public transport vehicles. Measured Gross Vehicle Weight (GVW) was compared to manufacturers' Gross Vehicle Weight Rating (GVWR) to assess the vehicle loading conditions. Data were collected in a twelve month period which included weekdays, weekends, market days and festive periods to capture representative annual loading characteristics

➢ *Sampling Procedure*

Ten high-volume interstate transport terminals of R1–R10 were purposively selected based on traffic volume and route coverage. A total of 500 fully loaded commercial vehicles (50 vehicles per terminal) comprising Toyota Hiace buses, Toyota Sienna vehicles, Toyota Sharon vehicles, and Peugeot 504 Station Wagons were assessed immediately before departure.

Table 1 Distribution of Sampled Vehicles

Route Code	Vehicle Type	Sample Size
R1	Toyota Hiace	50
R2	Toyota Hiace	50
R3	Toyota Hiace	50
R4	Toyota Sienna	50

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R5	Toyota Sienna	50
R6	Toyota Sienna	50
R7	Toyota Sharon	50
R8	Toyota Sharon	50
R9	Toyota Sharon	50
R10	Toyota Sharon	50

➢ *Data Collection*

Field measurements were conducted immediately before vehicle departure. For each sampled vehicle, the following parameters were recorded.

- Route and type of vehicle
- Number of passengers
- Weight of driver
- Weight of passengers
- Weight of luggage/cargo
- Fuel condition
- Manufacture's gross vehicle weight rating (GVWR)
- Measured gross vehicle weight (GVW)

Vehicle specifications were obtained from manufacturers' technical manuals and verified using standard automotive databases.

➢ *Determination of Gross Vehicle Weight (GVW) and Vehicle Load Compliance*

Vehicle loading was evaluated by comparing the measured Gross Vehicle Weight (GVW) with the manufacturer's Gross Vehicle Weight Rating (GVWR). The GVW was determined as the sum of the curb weight, passengers, driver, luggage, and fuel.

The GVW was evaluated as,

$$\mathrm{GVW} = \mathrm{W_c} + \mathrm{W_p} + \mathrm{W_d} + \mathrm{W_l} + \mathrm{W_f} \qquad (1)$$

Where,

$\mathrm{W_c}$ = curb weight
$\mathrm{W_p}$ = passenger mass
$\mathrm{W_d}$ = driver weight
$\mathrm{W_l}$ = luggage/cargo weight
$\mathrm{W_f}$ = fuel weight

Vehicle compliance was evaluated by comparing measured GVW with the corresponding manufacturer's GVWR.

The Vehicle Load Compliance Ratio (VLCR) was calculated as,

$$\mathrm{VLCR} = \frac{\mathrm{GVW}}{\mathrm{GVWR}} \qquad (2)$$

Where

$$\mathrm{VCLR} \leq \text{indicate Complince}$$

$$\mathrm{VCLR} \geq \text{indicate overloading}$$

The percentage overload was computed as

$$\%\ \mathrm{Overload} = \frac{\mathrm{GVR-GVWR}}{\mathrm{GVWR}} \mathrm{x}100 \qquad (3)$$

The manufacturer's GVWR and maximum passenger capacity are given in Table2.

Table 2 Manufacturer's GVWR and Standard Passenger Capacity of the Investigated Vehicles

Vehicle	**Passenger Capacity**	**GVWR (kg)**
Toyota Hiace	15	3300
Toyota Sienna	8	2580
Toyota Sharon	7	2170
Peugeot 504 Station Wagon	8	1866

➢ *Passenger and Cargo Measurements*

Passenger occupancy was determined by direct counting before vehicle departure. Passenger body weights were measured using calibrated digital scales where practicable; otherwise, standard adult body weights recommended by the Federal Road Safety Corps (FRSC) were adopted. Passenger luggage and commercial goods were weighed using calibrated electronic platform scales, while fuel weight was estimated from the measured fuel level. Measurements were made over the 12 months of the study period to capture normal and festive travel conditions.

➢ *Quality Assurance and Ethical Considerations*

All weighing instruments were calibrated before use and duplicate measurements were taken on randomly selected vehicles to ensure accuracy. The vehicle specifications were validated using manufacturer's manuals and field records were checked daily for completeness. Approval was obtained from transport unions and motor park management before data collection, while vehicle and park identities were anonymized to maintain confidentiality.

III. RESULTS AND DISCUSSION

The present study provides an engineering evaluation of passenger and payload overloading among commercial public transportation vehicles operating within Edo North Senatorial District, Nigeria. Table 3 shows the various standard loading characteristic of the vehicles obtained from the manufacturer's manuals. It serves as the basis for determining the degree of overloading.

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Table 3 Manufacturer's Standard Loading Characteristics of Vehicles Under Study

Vehicle	GVWR (kg)	Curb Weight (kg)	Payload Capacity (kg)	Standard Occupants (Including Driver)	Occupant Weight @75 kg/person (kg)	Available Cargo Capacity (kg)
Toyota HiAce	3300	2015	1285	15	1125	160
Toyota Sienna	2580	1930	650	8	600	50
Toyota Ipsum (Toyota Sharon)	2170	1620	550	7	525	25
Peugeot 504	1866	1260	606	8	600	6

➢ *Passenger and Cargo Loading Characteristics*

Annual loading characteristics are summarized in Tables 4–7. Passenger overloading occurred across all vehicle categories, although the magnitude differed among routes. Toyota Hiace buses recorded the highest average cargo load of 151.3 kg, while Toyota Sharon had the highest passenger overloading at 42.9%. The passenger overloads were always at 25.0% for the Toyota Sienna and Peugeot 504 Station Wagon vehicles. The findings showed that passenger loading was the main factor that contributed to GVW violation.

Table 4 Annual Loading Characteristics of Toyota Hiace Buses

Route Code	Average Passenger Load	Average Cargo (kg)	Passenger Overload (%)
R1	15.33	151.3	2.2
R2	16.00	151.3	6.7
R3	18.00	151.3	20.0

Table 5 Annual Loading Characteristics of Toyota Sienna Vehicles

Route Code	Average Passenger Load	Average Cargo (kg)	Passenger Overload (%)	Route Code
R4	10.00	147.1	25.0	R4
R5	10.00	85.0	25.0	R5
R6	10.00	87.9	25.0	R6

Table 6 Annual Loading Characteristics of Toyota Sharon Vehicles

Vehicle/Route	Average Passenger Load	Average Cargo Load (kg)	Passenger Overloading (%)
Toyota Sharon – Kaduna	10.00	102.9	42.9
Toyota Sharon – Warri	10.00	99.6	42.9
Toyota Sharon – Ibadan	10.00	99.6	42.9
Toyota Sharon – Ilorin	10.00	104.6	42.9
Peugeot 504 Station Wagon – Igarra	10.00	114.6	25.0

Table 7 Comparative Summary of Vehicle Loading Characteristics

Vehicle Type	Average Cargo (kg)	Passenger Overload (%)	Risk Level
Toyota Hiace	151.3	2.2–20.0	Moderate–High
Toyota Sienna	106.7	25.0	High
Toyota Sharon	101.7	42.9	Very High
Peugeot 504 Station Wagon	114.6	25.0	High

➢ *Passenger Overloading Variation in the Study*

The results indicate that passenger overloading is still a common operational practice for all vehicle types, but the severity level is different based on vehicle type and route. The Toyota Sharon vehicles had the highest passenger overloading of 42.9% followed by the Toyota Sienna and Peugeot 504 Station Wagon vehicles at 25.0%. The Toyota Hiace buses had relatively low passenger overloads of 2.2–20.0%.

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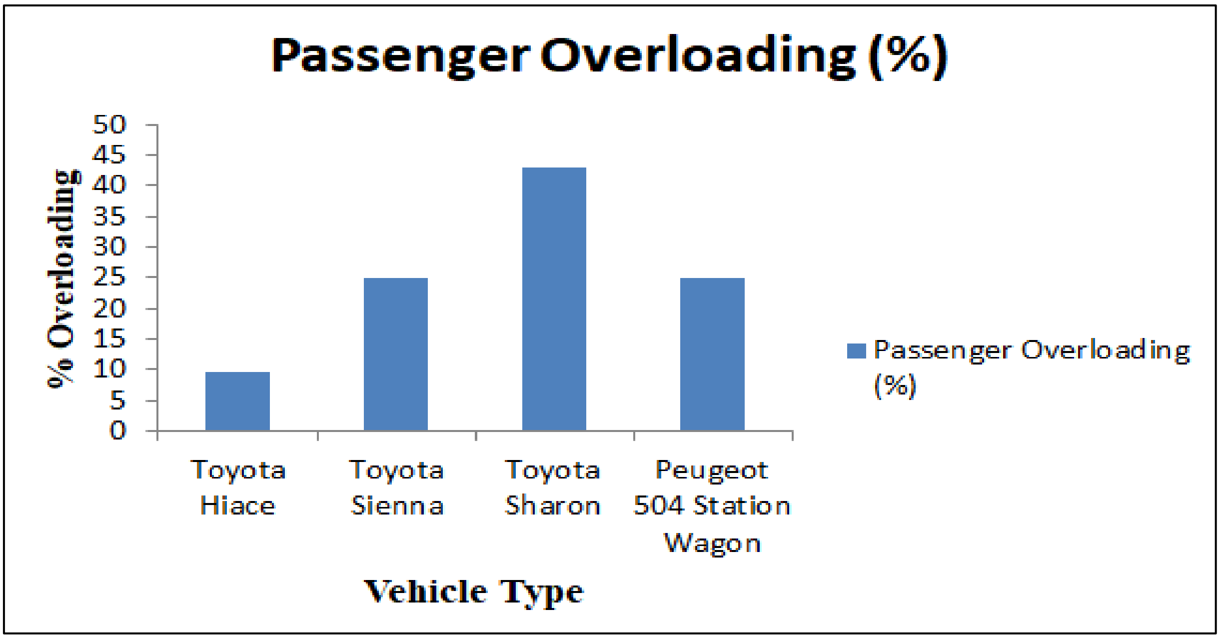

Fig 2 Passenger Overloading

Regular disregard for the manufacturers' recommended seating capacities is seen in the consistent overloading of Toyota Sharon and Toyota Sienna vehicles. When a vehicle is continuously operated under overload, the Gross Vehicle Weight exceeds the Gross Vehicle Weight Rating (GVWR) and stresses on the suspension, braking system, tyres, wheel bearings and chassis are beyond their design limits. These conditions reduce braking efficiency, increase stopping distance, accelerate tyre wear and adversely affect vehicle stability, especially during emergency maneuvers and high-speed interstate operations. Similar observations have been reported by [5] and [6] who showed that excessive vehicle loading significantly compromises braking performance and dynamic stability while increasing accident risk.

➢ *Cargo Overloading Characteristics*

Toyota Hiace buses had the highest annual average cargo load of 151.3 kg, indicating larger luggage capacity and frequent use on long-haul interstate routes. This is shown in Figure 3.

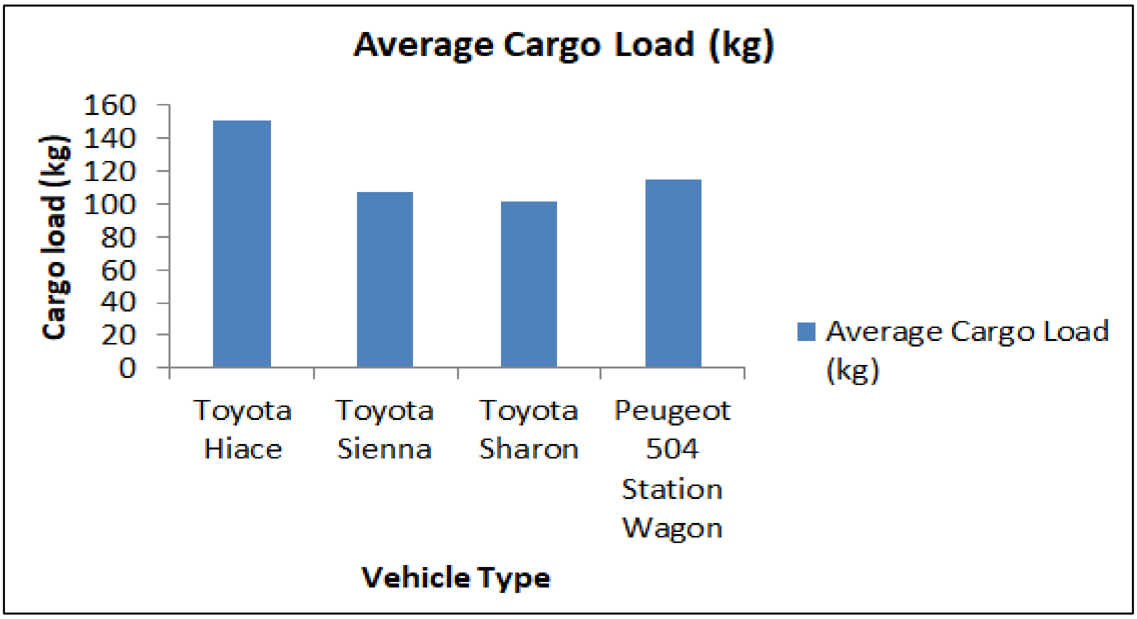

Fig 3 Annual Cargo Loading of the Vehicles

For the smaller vehicles, the average cargo load of 147.1 kg for the Toyota Sienna was highest on the Benin corridor on route R4, while the lowest averages of 87.9 kg and 85.0 kg were on the Onitsha Route R5 and Ekpoma Route R6 corridors respectively (Table 6). Toyota Sharon vehicles had fairly consistent cargo loads, with annual averages ranging from 99.6 kg to 104.6 kg, suggesting similar cargo loading practices across all routes analyzed. The average cargo load of Peugeot 504 Station Wagon was 114.6 kg, which was higher than Toyota Sharon but lower than Toyota Hiace and the heavily loaded Toyota Sienna route.

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Table 6 Annual Average Cargo Loading Characteristics of the Investigated Commercial Vehicles

Vehicle Category	Route Code	Route Description*	Mean Cargo Load (kg)	Minimum (kg)	Maximum (kg)	Standard Passenger Capacity	Loading Pattern
Toyota Hiace	R1	Abuja Corridor	151.3	90	250	15	High
Toyota Hiace	R2	Benin Corridor	151.3	90	300	15	High
Toyota Hiace	R3	Abuja Corridor (Operator B)	151.3	90	250	15	High
Toyota Sienna	R4	Benin Corridor	147.1	90	200	8	High
Toyota Sienna	R5	Onitsha Corridor	87.9	50	120	8	Moderate
Toyota Sienna	R6	Ekpoma Corridor	85.0	50	120	8	Moderate
Toyota Sharon	R7	Kaduna Corridor	102.9	50	140	7	Moderate
Toyota Sharon	R8	Warri Corridor	99.6	50	140	7	Moderate
Toyota Sharon	R9	Ibadan Corridor	99.6	50	140	7	Moderate
Toyota Sharon	R10	Ilorin Corridor	104.6	50	150	7	Moderate–High
Peugeot 504 Station Wagon	R11	Igarra Corridor	114.6	50	200	8	Moderate

The results indicate that the main carriers of passenger luggage were Toyota Hiace buses, whereas cargo loading was more evenly distributed among Toyota Sharon vehicles.

Cargo loading showed a clear seasonal variation, with the highest values being generally recorded in January, November and December which correspond to festive travel and increased commercial activities. The Toyota Hiace buses always carried the most cargo, due to their larger luggage compartments and higher demand for passengers on interstate routes. Although loading of cargo contributed to the increase in GVW, the findings revealed that overloading of passengers was still the major factor affecting vehicle load compliance. Similar seasonal loading patterns are observed in developing transport systems where an increase in passenger mobility during festive periods significantly increases the vehicle operating loads and road safety hazards [14], [4].

The comparative assessment also revealed that Toyota Sharon vehicles presented the biggest operational safety concern despite having lower average cargo loads than Toyota Hiace buses. This suggest that the passenger loading has more effect to the overloading of the vehicle. The weight of passengers is distributed over the passenger compartment and, in turn, affects the vehicle's centre of gravity, increases dynamic axle loadings and lowers steering stability. In these conditions, the deflection of the suspension, the contact stresses of the tyre and the rollover tendency increase substantially, particularly on curved road sections and under sudden braking. These results are consistent with those reported by [6], where it was shown that overloading of passengers greatly increases the instability of the vehicle and the severity of the accident.

The implications for engineering go far beyond vehicle performance and affect highway infrastructure. Overloading vehicles repeatedly results in excessive axle loads that speed up pavement deterioration by causing fatigue cracking, rutting, permanent deformation and reducing pavement service life. The highest passenger overloading was observed in Toyota Sharon vehicles; however, the contribution of the Toyota Hiace bus to pavement deterioration is likely to be more significant owing to its higher Gross Vehicle Weights associated with higher cargo loading. Similar findings were reported by [7] and [2], where they identified excess axle loading as a major cause of early pavement failure, diminished structural capacity and increased highway maintenance costs.

The observed loading characteristics have also important economic and environmental implications. As cars get heavier, the engine has to work harder and there is more rolling resistance, meaning more fuel is used, more greenhouse gases are emitted and energy efficiency falls. Also, overloading of vehicle parts like suspension parts, tyres, braking systems and driveline assemblies results in a higher rate of wear and tear and hence, increased maintenance and higher operating cost of the vehicle. These effects undermine fleet reliability, reduce the service life of components and reduce overall efficiency and sustainability of commercial passenger transportation. Similar results were reported by [15] and [16] who demonstrated that the overuse of vehicles causes an increase in fuel consumption, vehicle operational costs, pavement deterioration, and environmental impacts.

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➢ *A One-way ANOVA Analysis*

The one-way ANOVA on the monthly cargo-loading data revealed a statistically significant difference in mean cargo loads across the vehicle categories studied of $F(3,44) = 4.48$, and $p = 0.0079$. Toyota Hiace buses carried the greatest volume of cargo, although average cargo loads did not exceed the manufacturer's estimated payload capacities. Therefore, passenger overloading, not cargo loading, was found to be the major cause of GVW violations.

The loading characteristics observed also have important economic and environmental implications. Weight on a vehicle adds load to the engine and rolling resistance which means more fuel consumption, more greenhouse gas emissions and less energy efficiency. Overloading vehicles also increases wear and tear on suspension parts, tyres, braking systems, driveline assemblies, leading to higher maintenance needs and increased vehicle running costs. These effects reduce the reliability of fleets, shorten the service life of components, and decrease the efficiency and sustainability of commercial passenger transportation. According to [15] and [16], excessive vehicle loading increases fuel consumption, vehicle operating cost, pavement deterioration and environmental impact, with similar results. The Hiace buses had much higher cargo loads than the other vehicle categories, and Toyota Sharon vehicles had the lowest and most consistent cargo-loading pattern. The results suggest that vehicle type has a significant impact on cargo-loading behaviour in the study area. The ANOVA analysis is given in Table 7.

Table 7 One-way Anova for Monthly Cargo Loading Among Vehicle Categories

Source of Variation	**df**	**F-value**	**p-value**	**Decision**
Between vehicle categories	3	4.48	0.0079	Significant
Within vehicle categories	44	—	—	—
Total	47	—	—	—

IV. CONCLUSION

The study carried out an engineering assessment of passenger and payload overloading of commercial public transportation vehicles in Edo North Senatorial District, Nigeria using Gross Vehicle Weight (GVW) and Gross Vehicle Weight Rating (GVWR) as the main criteria for evaluation. The results confirmed that overloading of vehicles is still a common operational problem. The highest passenger overloading was observed in Toyota Sharon vehicles of 42.9% followed by Toyota Sienna and Peugeot 504 Station Wagon 25.0% overloading. Toyota Hiace buses had the highest annual average cargo load of 151.3 kg. Increased cargo loading in January, November and December reflects seasonal travel demand.

An exploratory one-way ANOVA revealed a significant difference in mean cargo loading across the investigated vehicle categories with $F(3,44) = 4.48$, $p = 0.0079$) thus confirming the impact of vehicle type on cargo-loading characteristics. Toyota Hiace buses carried the greatest volume of cargo, although average cargo loads did not exceed the manufacturer's estimated payload capacities. Therefore, passenger overloading, not cargo loading, was found to be the major cause of GVW violations.

Operation beyond manufacturers' loading limits is expected to increase braking distance, stresses on suspension and tyres, fuel consumption, vehicle instability and pavement deterioration, thus having a negative impact on road safety and the sustainability of transport. The study shows that the GVWR-based assessment with statistical analysis can be a practical engineering framework for vehicle load compliance assessment and high-risk transport operation identification.

The study suggests that passenger-capacity and payload regulations should be more strictly enforced through routine GVW inspections, use of intelligent weigh-in-motion (WIM) technologies and adoption of digital vehicle load-monitoring systems at major transport terminals. Future work should focus on the analysis of larger multi-state data sets using real time onboard weighing systems and vehicle dynamic modelling to develop predictive overload management strategies.

The study provides quantitative engineering and statistical evidence to support improved vehicle load management, improved regulatory enforcement, safer commercial transportation and more sustainable highway infrastructure management in Nigeria.

REFERENCES

[1]. African Development Bank Group, *African Economic Outlook 2024*. Abidjan, Côte d'Ivoire: African Development Bank Group, 2024.

[2]. Y. Gansonré, P. Breul, M. Benz, and R. Gourvès, "Effect of overloaded traffic on road pavement service life, structure and maintenance costs," *Journal of Transportation Technologies*, vol. 15, no. 3, pp. 313–334, 2025.

[3]. A. Nurhidayat and K. H. Kamarudin, "A systematic review of the impact of overload on road pavement," *International Journal of Transport Development and Integration*, vol. 8, no. 1, pp. 49–60, 2024.

[4]. World Health Organization, *Global Status Report on Road Safety 2023*. Geneva, Switzerland: World Health Organization, 2023.

[5]. L. Zheng, Y. Lu, J. Wang, *et al.*, "Braking failure anti-rollover control and hardware-in-the-loop verification of wire-controlled heavy vehicles," *Scientific Reports*, vol. 14, Art. no. 29802, 2024.

[6]. S. Zhang, X. Yang, Y. Liu, *et al.*, "TruckSim-based study of the rollover accident mechanisms of container semitrailers on freeway interchange loop ramps," *PLOS ONE*, vol. 19, no. 9, Art. no. e0309139, 2024.

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/26jul739

[7]. R. C. Prathapa, S. Velayudhan, and S. Mathew, "Impact of overloaded axles on the pavement service life: A case study of a two-lane national highway," *International Journal of Pavement Engineering*, vol. 26, no. 1, 2025.
[8]. S. V. Gomes, "The effect of overweight vehicles on road pavements and safety," *Transportation Research Procedia*, vol. 72, pp. 4010–4017, 2023.
[9]. K. Gkyrtis, "The impact of weight distribution in heavy battery electric vehicles on pavement performance: A preliminary study," *World Electric Vehicle Journal*, vol. 16, no. 9, Art. no. 520, MDPI on behalf of the World Electric Vehicle Association (WEVA), Sep. 2025, doi: 10.3390/wevj16090520
[10]. E. O. Rocheti and R. M. Bacurau, "Weigh-In-Motion systems review: Methods for axle and gross vehicle weight estimation," *IEEE Access*, vol. 12, pp. 134822–134836, 2024.
[11]. K. Lippa, J. Konijnenburg, L. Minnich, T. Pandya, and J. Willis, *Certification Approaches for Weigh-In-Motion Systems in Law Enforcement Applications*, NIST Special Publication 2200-05. Gaithersburg, MD, USA: National Institute of Standards and Technology, 2024.
[12]. M. O. Eruotor and T. A. Taiwo, "Leveraging technology for enhanced road transportation in Nigeria: A review of recent advances and innovations," *Nigerian Journal of Logistics and Transport*, vol. 16, no. 1, 2024.
[13]. M. Sujon and F. Dai, "Application of weigh-in-motion technologies for pavement and bridge response monitoring: State-of-the-art review," *Automation in Construction*, vol. 130, Art. no. 103844, 2021.
[14]. International Transport Forum, *Road Safety Annual Report 2024*. Paris, France: OECD Publishing, 2024.
[15]. H. Li, Y. Wang, X. Zhao, and M. Chen, "Influence of payload on braking performance, fuel consumption and energy efficiency of commercial vehicles," *Vehicle System Dynamics*, vol. 61, no. 8, pp. 1985–2004, 2023.
[16]. Q. Zhou, A. Ramakrishnan, M. Fakhreddine, E. Okte, and I. L. Al-Qadi, "Impacts of heavy-duty trucks on flexible pavements: Energy consumption, emissions and infrastructure sustainability," *International Journal of Pavement Engineering*, vol. 25, no. 1, 2024.