

SUSTAINABLE ROAD FREIGHT DISTRIBUTION AND CORRIDOR LOGISTICS PERFORMANCE ON MAJOR FREIGHT ROUTES IN LAGOS

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DOI10.51459/jostir.2026.2.2.097

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History

Received: 02-09-2025

Accepted: 21-04-2026

Published: August, 2026



<https://www.futa.edu.ng>



<https://jostir.futa.edu.ng>

ABSTRACT

This study investigated the spatial and operational logistics patterns within seven signature freight routes in Lagos that supports sustainable freight distribution. Specifically, it quantified 19-years (2005–2023) trends in freight vehicle registration, and accident rate. Using a mixed-methods approach, the study revealed that safety non-compliance increased by 3,612.45 incidents posing sustainability and safety risks. Further, the freight mobility for Lagos-Ibadan corridor stood at 28,153 with 32.5% modal share, while Oshodi-Apapa at 4,021.86 with 10.55% modal share, and Lekki-Epe at 1,677.1 with 3.29% modal share. These outcomes underscore critical infrastructure needs, and policy recommendations for cluster-based infrastructural investment, and targeted regulatory enforcement aimed at improving safety, efficiency, and logistics performance. Findings offer actionable insights for road freight policy, transport planning, and sustainable logistics ecosystem in Lagos.

Keywords: logistics, patterns, policy, infrastructure, enforcement, compliance.

1. | Introduction

Urban freight logistics in megacities like Lagos, Nigeria, plays a critical role in supporting economic growth, trade facilitation, and the timely delivery of goods across the supply chains. However, the operational dynamics of road freight logistics in Lagos are characterised by a complex interplay of infrastructural limitations, traffic congestion, regulatory and compliance gaps, and spatial disparities in road freight vehicle demand and supply (Adeyemo and Magaji 2020). These factors significantly shape the patterns of freight traffic flow and physical distribution along key freight corridors, often resulting in inefficiencies, increased transportation costs, environmental degradation, and compromised sustainability. The rapid

urbanisation and economic growth of Lagos have led to an exponential increase in freight distribution and transportation demand. As the largest city in Africa by population and Nigeria major commercial hub, Lagos faces significant logistical challenges hindering the sustainability of road freight distribution and efficiency (Buhari *et al.*, 2025).

Adeniran *et al.* (2020) opined that sustainable road freight distribution involves optimising logistics operations to minimise the adverse effects of poor freight conditions, economic hardships, and congestion while maintaining cost efficiency and reliability. Given Lagos's logistics economy reliance on road transport and the underutilization of rail and waterway alternatives, understanding

freight logistics patterns on key road freight routes is essential for developing a data-driven policies and strategies (Adekunle, 2026). The trend and rate of change of registration and deployment of new operational freight vehicles, extent of compliance of freight vehicles to regulatory and safety standards, traffic accident records, and the frequency of non-compliance have implications on the sustainability of road freight and physical distribution systems development (Adeniran *et al.*, 2020 and World Bank, 2019).

Ndikom *et al.* (2018) and Anthony (2014) noted that Lagos, the commercial nerve center of Nigeria and one of Africa's fastest-growing urban agglomerations, presents a unique logistics environment. It serves as a central node for national and regional freight movement, driven by high volumes of inbound and outbound goods from ports, industrial zones, markets, and urban retail hubs (Nwokedi *et al.*, 2021; Ogunbodede, 2019). Despite its strategic logistics potential, the city's freight systems face systemic challenges such as uncoordinated routing, poor infrastructure maintenance, inadequate warehousing integration, accidents arising from non-compliance to traffic regulations, poor budgetary allocations to transport sector development, traffic congestion and conflicting land use policies (Buhari *et al.*, 2025). Road freight routes such as the Lagos-Ibadan Express Route (LIER), Oshodi-Apapa Express Route (OAER), and Lekki-Epe Express Route (LEEP) are believed to handle majority of road freight logistics and distribution operations in Lagos, but there is gross inadequacy of empirical information and knowledge of the average number of freight trucks operating on each route relative to the available road infrastructural informing a basis for planning sustainable road freight operations (Nwokedi *et al.*, 2021; Ogunbodede, 2019). Similarly, information on the trend and rate of change of registration and deployment of new operational freight vehicles, extent of compliance of freight vehicles to regulatory and safety standards, traffic accident records,

frequency of non-compliance on the routes which have implications on the sustainability of road freight and physical distribution systems development are also pertinent to traffic planning (Buhari *et al.*, 2025).

Addressing the challenges requires a comprehensive analysis of freight movement patterns, stakeholder behaviors, and infrastructure constraints to project sustainable logistics solutions with a focus on the study objectives. The study aims to analyze logistics patterns on key routes in Lagos and its implications on sustainable freight distribution. This research will further investigate the spatial and operational patterns of road freight logistics along the identified corridors as well as explore the implications on developing a resilient and sustainable logistics ecosystem. From a broader angle, this research contributes to the debate about sustainable freight distribution networks in rapidly urbanized cities in Africa. This demonstrates the necessity of adaptive logistics systems that balance economic development and transportation systems. The ultimate aim of this research is to develop a sustainable freight distribution system that is specific to the environment and adaptable in terms of technology.

2. | Materials and Methods

The road freight network is important for the urban economy and the national economy as well; especially in a fast urbanizing city such as Lagos where road transport makes up over 90% of internal freight movements (Adewumi *et al.*). However, road freight logistics is increasingly scrutinized for its environmental impacts, inefficiencies, and contribution to urban congestion and air pollution (UN-Habitat, 2020). Sustainability in this context involves the optimization of distribution patterns, thereby, reducing emissions, and enhancing operational efficiency (McKinnon *et al.*, 2010).

Triple Bottom Line (TBL) framework underpinned sustainable freight transport by measuring the balance between economic viability, environmental protection, and social equity (TODD, 2017; Adeleke *et al.*, 2021; Onakomaiya *et al.*, 2022). Within this framework, logistics pattern is defined as the regularities in freight movement, route choices, and scheduling aimed at establishing efficiency, ecological balance, and social footprints (Behrends *et al.*, 2008). The Green Logistics Theory further supports the idea of controlling transportation externalities through the application of technology and innovations (McKinnon *et al.*, 2010). Lagos faces significant challenges with freight distribution due to inadequate road infrastructure, high vehicle density, and poor regulatory enforcement (Olawole & Aloba, 2021). Afolabi & Gbadamosi (2017) identified that Apapa-Oshodi, and Lagos-Ibadan corridors as major freight routes, often congested resulting to mobility delays, non-compliance to traffic standards, and environmental pollution.

In addition, Empirical studies in Lagos revealed a need for data-driven freight flow models. For example, Ogunleye *et al.* (2018) used GPS data to track delivery trucks and found high travel time uncertainty. Ogunleye *et al.* (2018) concluded that high travel time uncertainty influences road freight operators route choice and have implications on sustainable road freight logistics planning. This occasioned increased travel time as a result of congested road freight routes resulting to delay and its associated increased in transportation cost (Buhari *et al.*, 2025). Oluwaseyi *et al.* (2019) used Geographic Information Systems (GIS) to map congestion hotspots along Lagos freight corridors and the study found that traffic congestion on these routes are trends responsible for significant increases in haulage cost. Adeniran *et al.* (2020) applied survey-based methods to assess driver challenges, identifying illegal tolls and lack of rest areas as recurring issues. These studies underline the fragmented nature of Nigeria's road freight system

and highlighted the potential of predictive analytics and policy reform for sustainability.

Consequently, the study adopted a multidisciplinary approach that integrates route analysis, field survey, and historical approaches, thereby, bridging the knowledge gap between road freight logistics operations and urban sustainability planning in Lagos Metropolis. Qualitative and survey research design methods in which primary data were obtained using questionnaire and checklist as survey instrument while secondary data was obtained from the Lagos Transport Ministry and statistical analysis were implemented in line with the objectives of the study while the results and findings were discussed. The study spatial coverage of Lagos signature road freight corridors of Lagos-Ibadan Express Route (LIER), Oshodi-Apapa Express Route (OAER), and Lekki –Epe Express Route (LEEP) were considered because these locations are peculiar to receiving logistical operations because of their proximity to economic infrastructural zones (in essence, the port, refinery, and industrial layout).

Furthermore, the study adopted field survey method to obtain primary data from road freight operators Lagos metropolis. The data obtained traffic count flow across all the three (3) identified freight routes with the use of traffic count field survey approach. The observational traffic survey method was used to obtained hourly, daily and weekly road freight traffic flow across Lagos-Ibadan Express Route (LIER), Oshodi-Apapa Express Route (OAER), and Lekki –Epe Express Route (LEEP).

The secondary data (2005-2023) was also used to complement the primary data. The secondary data was sourced from the Lagos Ministry of Transportation, Ministry of Economic Planning and Budget, and the Federal Road Safety Commission (FRSC) Lagos. The data obtained from these sources include data on the annual registration new freight vehicles, the extent of compliance to standards and

safety regulations, the extent of non-compliance to standards and regulations and the frequency of traffic accidents involving freight vehicles. The secondary data was used in each case to estimate the rate of change of budgetary allocation to transport development in Lagos.

The Rate of Change Analysis (RCA), the Traffic Count Analytics method, descriptive and inferential Statistics quantitative methods were used to analyzed the dataset obtained; specifically for the objectives of the study. The objectives were addressed using the

derivative of functions or rate of change methods. The study estimated the coefficient of the average rate of change of new freight vehicle deployment in Lagos metropolis (LAGREGISTEREDTRUCKS), extent of regulatory compliance by road freight vehicle operators in Lagos (SAFETYCOMPLIANCEREC), accident levels involving road freight vehicles in Lagos (FREIGHTVEHACCIDENT), extent of non-compliance to regulatory standards in Lagos (LAGNONCOMPLANCE) and transport sector budget allocation in Lagos (LAGTRPBUDGET).

Basically, the average rate of change from the interval $[t_1 \dots t_{19}]$ covering the 19-year period covered in the study from 2005 to 2023 can be estimated from the expression:

$$\frac{\Delta Y}{\Delta t} = \frac{f(\text{LAGREGISTEREDTRUCKS}_1) - f(\text{LAGREGISTEREDTRUCKS}_{19})}{T_1 - T_{19}} \quad (1)$$

For new freight vehicle registration and deployment (LAGREGISTEREDTRUCKS), the average rate of change coefficient is determined as:

$$\frac{\Delta \text{LAGREGISTEREDTRUCKS}}{\Delta t} = \frac{(\text{LAGREGISTEREDTRUCKS}_1) - (\text{LAGREGISTEREDTRUCKS}_{19})}{T_1 - T_{19}} \quad (2)$$

For compliance to standards and safety regulations, (SAFETYCOMPLIANCEREC), the average rate of change over the period is determined as:

$$\frac{\Delta \text{SAFETYCOMPLIANCEREC}}{\Delta t} = \frac{f(\text{SAFETYCOMPLIANCEREC}_1) - f(\text{SAFETYCOMPLIANCEREC}_{19})}{T_1 - T_{19}} \quad (3)$$

Where $f(t_1)$ and $f(t_{19})$ are the values of the variables corresponding to the first and last year within the period covered in the study.

For traffic accident involving freight vehicle operators in Lagos (FREIGHTVEHACCIDENT), the average rate of change over the period is determined as:

$$\frac{\Delta \text{FREIGHTVEHACCIDENT}}{\Delta t} = \frac{(\text{FREIGHTVEHACCIDENT}_1) - (\text{FREIGHTVEHACCIDENT}_{19})}{T_1 - T_{19}} \quad (4)$$

For extent of non-compliance of freight vehicle operators in Lagos metropolis to standard regulations (LAGNONCOMPLANCE), the average rate of change over the period is determined as:

$$\frac{\Delta \text{LAGNONCOMPLANCE}}{\Delta t} = \frac{(\text{LAGNONCOMPLANCE}_1) - (\text{LAGNONCOMPLANCE}_{19})}{T_1 - T_{19}} \quad (5)$$

For budgetary allocation to transport sector development in Lagos metropolis (LAGTRPBUDGET), the average rate of change over the period is determined as:

$$\frac{\Delta LAGTRPBUDGET}{\Delta t} = \frac{(LAGTRPBUDGET_1)-(LAGTRPBUDGET_{19})}{T_1 - T_{19}}$$

(6)

It is important to note that the OLS estimation where the time [t_1 --- t_{19}] is the independent variable can be used to determine the trend of each variable over the period covered in the study. The coefficient of the OLS regression or trend analysis where time is the explanatory variables is equivalent to the average rate of change coefficients for each variable over the period covered in the study. Using equations (1) to (6) respectively, the study addressed the first objectives of the study. In addition, the study also deployed count survey method, descriptive, and inferential statistics to analyze periodic freight traffic flow

patterns on the identified routes forming the basis for sustainable road freight logistics.

3. | Results and Discussion of Findings

Table 1: Descriptive Statistics providing Empirical Evidence of new Freight Vehicles Registration, Traffic Accidents, regulatory Compliance and Budget Allocation to Transport in Lagos State (2005 – 2023).

Table 1 | Descriptive Statistics Providing Empirical Evidence of New Freight Vehicles Registration, Traffic Accidents, Regulatory Compliance and Budget Allocation to Transport in Lagos State (2005 – 2023).

	N	Range	Minimum	Maximum	Sum
LAGREGISTEREDOPRTRUCKS	19	9686.00	217.00	9903.00	67760.00
LAGSAFETYCOMPLIANCEREC	19	13511.00	1780.00	15291.00	184587.00
LAGNONCOMPLANCEREC	19	98892.00	999.00	99891.00	436933.00
FREIGHTVEHACCIDENTREC	19	957.00	42.00	999.00	6971.00
LAGTRPINFRBUDGET	19	482855315200.0	4684800.00	482860000000.00	1877070707800.00
Valid N (listwise)	19				
Descriptive Statistics					
		Mean	Std. Deviation		
LAGREGISTEREDOPRTRUCKS		3566.3158	2987.00469		
LAGSAFETYCOMPLIANCEREC		9715.1053	3746.16045		
LAGNONCOMPLANCEREC		22996.4737	26450.97363		
FREIGHTVEHACCIDENTREC		366.8947	393.11984		
LAGTRPINFRBUDGET		98793195147.3684	115281322111.66992		
Valid N (listwise)					

Source | Author’s calculation (2025)

The result shown in Table 1 present a characteristic evidence of the extent of registration of new freight vehicles (trucks) for distribution by road freight operators in Lagos, the frequency or extent of compliance and non-compliance to standard

regulations in Lagos, the frequency and extent of traffic accidents involving freight vehicles and the budgetary allocation to the development of the transport sector in Lagos in view of the features of the road freight sector covering a 19 years period.

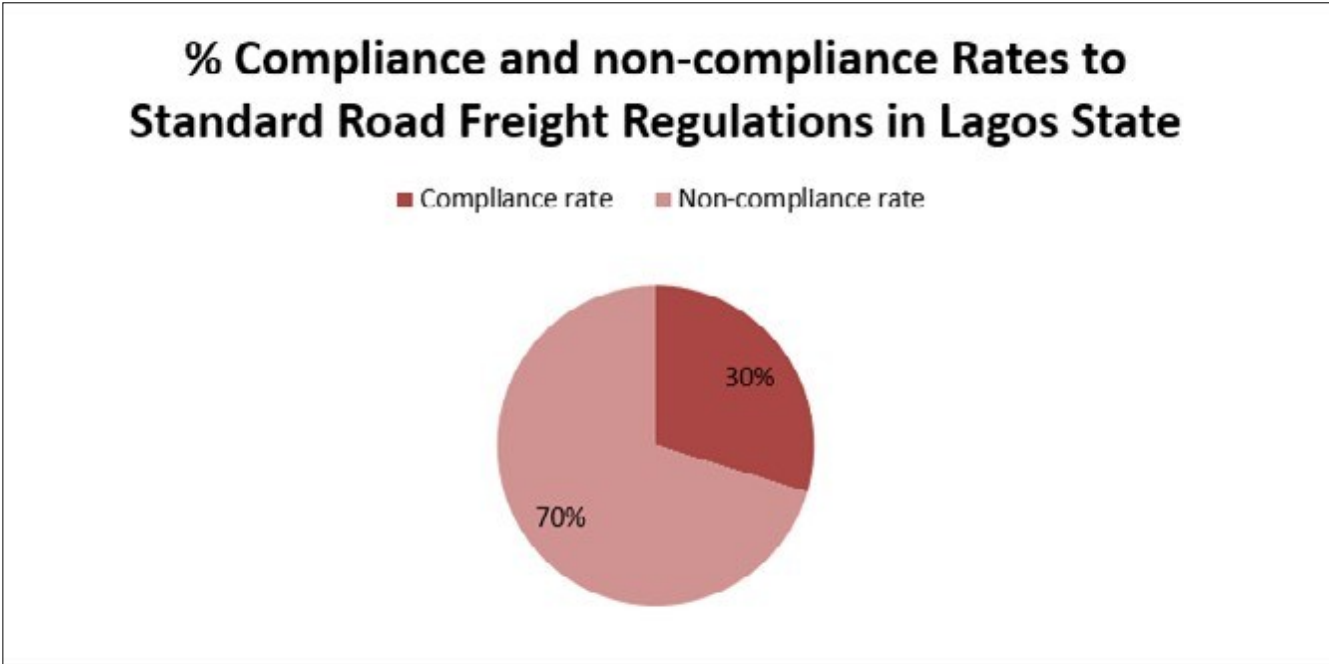
The result indicates that the average number of newly registered freight vehicles deployed for distribution by road freight operators across routes in Lagos metropolis is 3566.33 freight trucks (vehicles) with a standard deviation of 2987.004 per annum between 2005 and 2023 while an aggregate of 67760.00 new freight trucks/vehicles were acquired and deployed for freight distribution within Lagos Metropolis over the 19 years' period. This implied that each year between 2005 and 2023, new freight vehicles were registered by road freight operators in Lagos for servicing the physical distribution needs and this has implications on the freight vehicle density, traffic safety, road infrastructural provision coupled with social and economic consequences. For example, increasing trend in new freight vehicle registration and use without corresponding increase and/or improvement in road infrastructural condition in the state may lead to increased traffic congestion, increased traffic accident as a result of increased competition for access to road infrastructure, congestion-related idle time with the social and economic consequences and this outcome is consistent with Ajiboye *et al.* (2021)

Furthermore, the result in Table 1 equally shows that a 9715.105 average level of compliance to standard traffic regulations with a standard deviation of 3746.161 per annum between 2005 and 2023. The aggregate sum of road freight operator's compliance to basic safety and traffic regulations and standards in Lagos Metropolis is 184587.00. The implication is that each year between 2005 and 2023, about 9715.105 freight vehicle operators satisfactory complied with traffic regulations related to road freight and physical distribution operations aimed at enhancing sustainable logistics and distribution in Lagos. This is important because compliance to standard regulations related to logistics and freight distribution have positive impacts in promoting sustainable patterns of logistics and freight transportation and the outcome is consistent with

Ribeiro (2012); Ramesh *et al.* (2022) and Sanchez-Diaz *et al.* (2016).

Further, Table 1 showed the extent of non-compliance to standard safety regulations in Lagos State by freight vehicle operators engaged in distribution of freight in Lagos with an average of 22996.474, and standard deviation of 26450.974 per annum between 2005 and 2023. The aggregate sum of road freight operator's non-compliance with standards safety regulations in Lagos Metropolis is 436933.00. This implied that each year between 2005 and 2023, an average of 22996.474 fails to satisfactorily comply with standard safety regulations related to road freight and physical distribution operations aimed at enhancing sustainable logistics and distribution of freight in the City and this supported Oluwaseyi *et al.* (2019). This situation is dangerous as it endangers sustainable mobility and freight distribution system in Lagos metropolises. This is because non-compliance to safety standards jeopardizes mobility safety and sustainability, with its attendant harsh socio-economic consequences. The pie chart on Figure 1 shows a far higher percentage non-compliance rate than compliance rate which is dangerous and unhealthy for the road freight distribution sector in Lagos. To guarantee a sustainable road freight distribution system, policies must be implemented to reverse this ugly trend in order to achieve a higher level compliance to standard safety regulations by operators in Lagos State.

The result in Table 2 indicated that an average of 366.895 with a standard deviation of 393.12 road freight vehicle operators get involved in traffic accident per annum between 2005 and 2023. An aggregate sum of 6971.00 road freight operators was involved in road accidents on signature road freight routes in Lagos Metropolis over the 19 years covered in the study. By implication, each year between 2005 and 2023, an average of 393.12 freight vehicle operators gets involved in traffic accident in Lagos. Similar to the non-compliance to standard safety



Source | Author (2025)

Figure 1 | % Compliance and non-compliance Rates to Standard Road Freight Regulations in Lagos State.

Table 2 | Coefficients of Average Rate of Change of New Registration of Freight Vehicles, Compliance to Regulations, Freight vehicle Accident Levels, Non-compliance to standards and Budget allocation to Transport Sector in Lagos (2005 – 2023)

Variable	R	R Square	F score	B ₀ (Constant)	B ₁ = Reg. Coef. = rate of change	t score	p-value
LAGREGISTE .EDTRUCKS	0.767	0.589	24.322	7638.667	-407.235	-4.932	0.000
FREIGHTVEH ACCIDENT	0.841	0.708	41.173	954.614	-58.772	-6.417	0.000
LAGNONCOM PLANCE	0.769	0.591	24.528	-13127.982	3612.446	4.953	0.000
LAGTRPBUD ET	0.424	0.179	3.718	12011017922.807	8678217722.45	1.928	0.071
SAFETYCOM LIANCEREC	0.398 ^a	0.159	3.205	7063.825	265.128	1.790	0.091

Source | Author’s calculation (2025)

regulations guiding freight vehicles, this situation is dangerous as accidents endangers the realization of sustainable mobility and freight distribution/ freight operators within metropolitan Lagos and this outcome validated Sharma & Mishra (2013); Tan (2016); UNDP (2020). Therefore, policies must be developed to address issues of frequent traffic accident involving road freight vehicles, thereby developing a sustainable mobility patterns for the road freight and physical distribution within the identified corridors.

In addition, the results of the study as shown in Table 2 and Figure 3 indicates the aggregate amount of budgetary allocation for the development of the transportation sector in Lagos over the 19 years’ period covered in the study from 2005 to 2023 is 1,877,070,707,800.00 Naira (1.8trillion naira). The average budgetary allocation to the development of the transport sector per annum is 98,793,195,147.37 (98.7billion) naira with a standard deviation of 115281322111.67. It is expected that these huge allocations will be deployed in overcoming

challenges to the realization of sustainable mobility patterns with regards to the distribution of freight in Lagos State. The result of the trend analysis provided empirical knowledge and information on the rates of change of budgetary allocation to transport, accident involving freight vehicle operators, new registration and use of freight vehicles, extent of compliance with and non-compliance with standard regulations in Lagos State. Therefore, adequate funding and actual spending on transportation infrastructure are required to achieve sustainability in the patterns of freight distribution and road freight vehicle operations within the identified corridors. This outcome is consistent with Buhari *et al.* (2025). Table 2 shows the result of the rate of change analysis aimed to provide knowledge and understanding of the trend of registration and deployment of new freight vehicles (LAGREGISTEREDTRUCKS) on the identified corridors, the extents of compliance (SAFETYCOMPLIANCEREC) and non-compliance (LAGNONCOMPLANCE) with regulatory standards in road freight transportation by operators in Lagos, the level of prevalence of

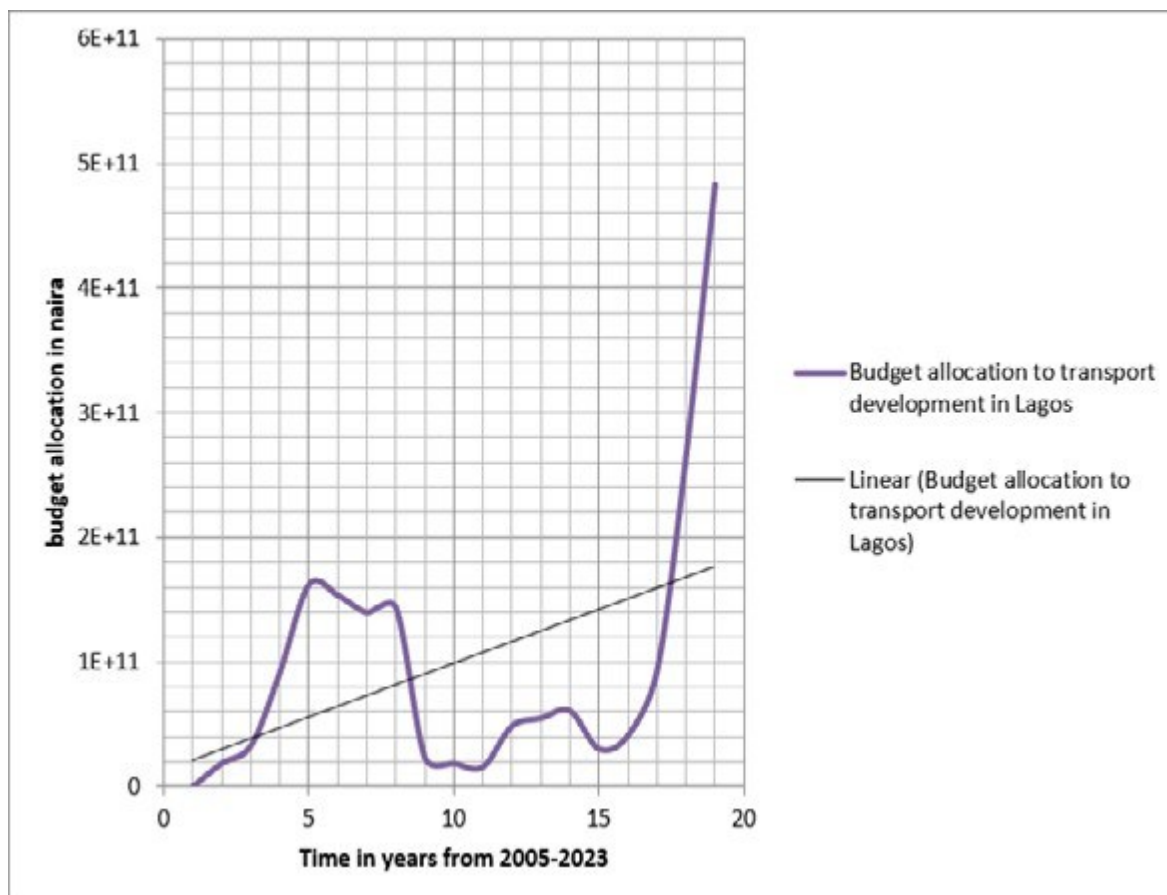
road traffic accidents (FREIGHTVEHACCIDENT) involving freight vehicles in Lagos and the budgetary allocation to transport sector development in Lagos state (LAGTRPBUDGET) as equally presented in Figure 2. However, the study revealed that sustainable mobility patterns can only be achieved with improved budgetary allocation to transport infrastructure development. This is expected to enhance the reduction of freight vehicles accidents, with the required interventions aimed at consistent deployment of roadworthy freight vehicles, and improvement in levels of infrastructure and smart technology aimed at improving compliance to standard traffic and safety regulations of road freight operators and stakeholders.

Based on the findings, it was revealed that the coefficient of the average rate of change of the registration and deployment of new freight vehicles by operators in Lagos metropolis over the 19 years' period between 2005 and 2023 is -407.23 with an intercept of 7638.667. This suggested that each year the number of freight vehicles registered and deployed



Source | Author (2025)

Figure 2 | Trend line showing pictorial view of the variations in new freight vehicle registration and deployment, compliance to standard safety regulations, non-compliance to standards and accident levels in Lagos metropolis (2005 – 2023).



Source | Author (2025)

Figure 3 | The line graph that shows the fluctuations in budgetary allocations for the development of the road transport sector in Lagos State (2005 – 2023).

for distribution in Lagos metropolis declined by an average rate of 407.23 freight vehicles, suggesting a declining trend in the registration and deployment of new freight vehicles across Lagos metropolis by road freight operators over the period. The trend equation showing the influence of time or trend of new registration and deployment of freight vehicles by operators in Lagos is:

$$LAGREGISTEREDTRUCKS = 7638.67 - 407.23T. \quad (7)$$

This declining trend and pattern in the registration and deployment of new freight vehicles by road freight operators on Lagos road freight sector is not healthy for sustainability in the physical distribution because it may lead to transport crisis in the future

where stakeholders may experience difficulty in accessing road freight transport services in the State. Road freight transport policies should thus be developed to achieve a satisfactory level of increasing rate of change in the registration and deployment of new freight vehicles for road freight operations, thereby reflecting a seeming growth in Lagos economic activities. Programmes and Policies can be developed and implemented to achieve annual increment in the deployment and registration of new freight vehicles in Lagos greater than or equal to the average rate of change coefficient per annum.

Similarly, the average rate of change coefficient depicting the trend of involvement of road freight vehicle operators in Lagos metropolis in traffic accident (FREIGHTVEHACCIDENT) over the 19

years' period is -58.77 per annum with intercept of 954.614. This implied that the rate of involvement of road freight vehicles in traffic accident across freight routes in Lagos metropolis decreased at an average rate of 58.77 per annum. The model showing the trend of the decline in involvement of road freight vehicle operators in traffic accident in Lagos over the period is:

$$FREIGHTVEHACCIDENT = 954.614 - 58.77T \quad (8)$$

The results and findings of the study reveal a declining trend or pattern in the involvement of freight vehicles in traffic accident in the identified freight routes which is good for sustainable road freight operations and physical distribution activities in the metropolis. However, it is important to mention that the decline is insignificant when compared to the attendant casualties of accident when it involves freight vehicles. Moreover, for a more significant impact, strategies and safety policies should be continuously implemented to achieve zero level of freight vehicle involvements traffic accidents in Lagos and the outcome is consistent with Buhari *et al.* (2025).

The result also revealed that the coefficient of the average rate of change of the extent of non-compliance of freight vehicle operators (LAGNONCOMPLANCE) to standard regulations over the 19-year period is an average of 3612.446 per annum while the intercept parameter is -13127.982. The result further reveals that the extent of non-compliance of road freight vehicle operators to standard traffic regulations guiding road freight operations increases by an average of 3612.446 non-compliance incidents each year which is based on objective 3. The implication is dangerous as it has negative consequences on the development of sustainable freight logistics and distribution patterns in Lagos metropolis. This is because increasing trend in non-compliance to standard regulations guiding

road freight operations in the Lagos metropolises could have negative socio-economic consequences such as accidents leading to deaths, injuries and damages to properties and consignments, traffic congestion and the associated consequences. The equation showing the trend of non-compliance of road freight vehicle operators to standard regulations guiding the road freight sector in Lagos Nigeria is:

$$LAGNONCOMPLANCE = -13127.982 + 3612.446T \quad (9)$$

To achieve a sustainable road freight logistics and physical distribution system in Lagos, road freight management policies must be developed to achieve a sustained declining trend in the extent of non-compliance of freight vehicle operators to standard regulations guiding road freight operations in the City. To ensure sustainable logistics and physical distributions systems, regulatory policy maker must ensure that the extent of non-compliance to standard regulations guiding operations of freight vehicles in Lagos metropolis decline by an amount greater than or equal to the average of change coefficient of 3612.446.

The result also shows that the rate of change of level of compliance to standard regulations (SAFETYCOMPLIANCEREC) guiding road freight operations in Lagos metropolis each year over the 19 years' period between 2005 and 2023 is an average of 265.128 with intercept parameter value of 7063.825. The model equation showing the trend of compliance with standard regulations by road freight vehicle operators in Lagos metropolis between 2005 and 2023 is:

$$SAFETYCOMPLIANCEREC = 7063.825 + 265.128T \quad (10)$$

This implied that each year between 2005 and 2025 the compliance of road freight vehicle operators across the identified routes increases by 265.128

compliances. Thus to ensure sustainable freight logistics and physical distribution operations in Lagos, road freight vehicles operators must be made to comply with standard regulations such that each year, the compliance rate must be made to increase by an amount greater than or equal to the average rate of change value of 265.128.

Lastly, the result also shows that the rate of change of budgetary allocation to the development of the transport sector in Lagos State each year over the 19 years' period (2005-2023) is an average of 8,678,217,722.45 naira with intercept parameter value of 12,011,017,922.81. The model equation showing the trend of budgetary allocation for the development of the transport sector in Lagos State (2005-2023):

$$\text{LAGTRPBUDGET} = 12011017922.81 + 8678217722.45T \quad (11)$$

This implied that each year between 2005 and 2025 the budgetary allocation for the development of the transport sector in Lagos increases by an average

of 8678217722.45 naira. Thus to ensure sustainable freight logistics and physical distribution operations in Lagos, policy makers in Lagos must ensure adequate budgetary allocations to the transport sector such that each year, the budgetary allocation for the development of the sector must increase by an amount greater than or equal to the average rate of change value of 8,678,217,722.45 naira. This will ensure that budgetary allocation to transport sector development in Lagos is adequate enough to ensure satisfactory levels of investment that guarantees the development of sustainable road freight and physical distribution systems in Lagos.

The result in Table 3 showed the average freight vehicle traffic flow rates across all the sampled freight routes in Lagos metropolis. The result and findings of the study indicates that the average weekly freight vehicle flow through all the identified freight routes is 28153/week with a standard deviation of 21204.87. The implication is that given the level of economic activities and development of the road freight sector in Lagos State, ensuring sustainability in the mobility pattern and the flows

Table 3 | Average Freight Vehicle Traffic Flow Rates through all the Identified Freight Routes in Lagos Metropolis (LIER, OAER, and LEEP).

Parameter	Per Hour	Per Day	Weekly
Mean(allroute)	167.7143	4021.857	28153
Standard Error	47.58037	1144.955	8014.686
Median	119	2844	19908
Standard Deviation	125.8858	3029.267	21204.87
Sample Variance	15847.24	9176456	4.5E+08
Kurtosis	-0.17671	-0.1802	-0.1802
Skewness	1.122951	1.122212	1.122212
Range	343	8254	57778
Minimum	39	922	6454
Maximum	382	9176	64232
LAGOS Sum	1174	28153	197071
Count	7	7	7

Source | Author's calculation (2025)

of freight logistics and physical distribution systems in Lagos demand that weekly flow of freight vehicles (WKFLFV) across the identified signature freight routes must be greater than or equal to an average of 28153 freight vehicles with standard deviation of 21204.87. That is, $WKFLFV_t \geq 28153$.

Similarly, the average hourly flow rate of freight vehicles per (HRFLFV) and daily flow rate of freight vehicles (DAFLFV) across all the sampled signature freight routes in Lagos metropolis is 167.714/hour and 4021.857/day with their respective standard deviations of 125.886 and 3029.267. The implications are that given the prevailing level of activities and development of the road freight sector in Lagos, the hourly flow rate of freight vehicles across the identified signature freight routes must be greater than or equal to an average of 167.714vehicles/hour while the daily freight vehicle flow rate across all the sampled freight routes must be greater than or equal to 4021.857vehicles/day. That is $HRFLFV_t \geq 167.714$; and $DAFLFV_t \geq 4021.857$.

Further, this also implied that the development of road infrastructure on across the sampled signature freight routes must be adequate to accommodate the average hourly, daily and weekly flow rates of road freight vehicles without impeding accessibility while safety infrastructure must be provided to

accommodate the needs of that level of freight vehicles accessing the identified routes hourly, daily, and weekly. Therefore, Investment in infrastructure should be progressive from the minimum level in order to accommodate and serve the needs of 167.74vehicles/hour, 4021.857vehicles/day and 28153vehicles/week and this validated Oluwaseyi *et al.* (2019).

The results in Table 4 and Figure 4 showed the percentages of hourly, daily and weekly freight vehicle flow rates and patterns on individual signature freight routes in Lagos metropolis. The result and findings of the study indicated that on the Lekki –Epe route (LEEP) freight vehicle hourly, daily and weekly flow pattern is 10.56%, 10.55% and 10.54% of aggregate freight vehicle flow rate in all signature freight routes sampled in Lagos metropolis. This gives an average of 10.55% of freight vehicle flow rate in all signature freight routes sampled in Lagos metropolis, indicating that the Lekki –Epe route (LEEP) carries an average of 10.55% of freight vehicle traffic across Lagos signature freight routes sampled in the study. The development of road infrastructure and safety policies to ensure sustainability of road freight and physical distribution operations on the route will also be based on the average freight traffic flow rates per period on the route.

Table 4 | % Freight Vehicle Traffic Flow Pattern on Individual Signature Freight Routes in Lagos metropolis (LIER, OAER, and LEEP).

S/N	Route/average number of trucks on each route	Average fleet per hour	Average fleet per day	Average weekly fleet		
1	All routes considered in Lagos Metropolis	167.7143	4021.857	28153	-	
2	Individual route analysis	fleet Per hour %	fleet Per day %	Weekly fleet %	Average	Lane width
3	Lekki –Epe route (LEEP)	10.56%	10.55%	10.54%	10.55%	4
4	Lagos-Ibadan route (LIER)	32.53%	32.59%	32.59%	32.57%	4
5	Oshodi-Apapa Express (route) (OAER)	3.32%	3.28%	3.28%	3.29	4

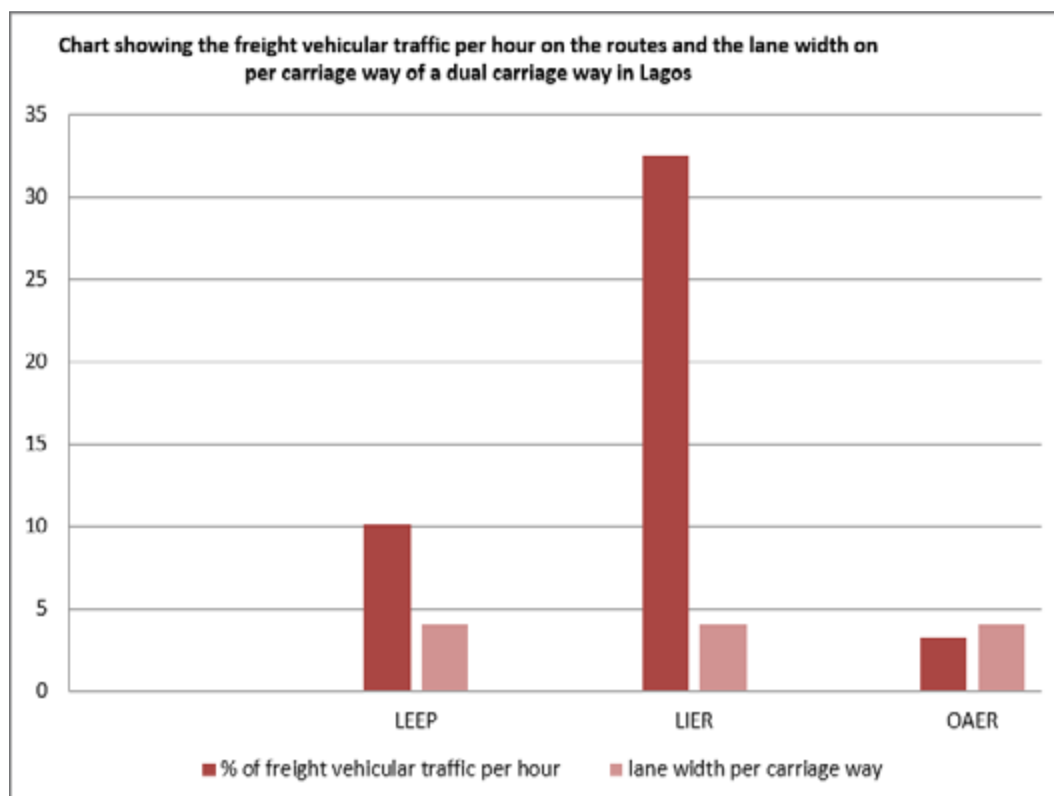
Source | Author's calculation (2025)

The Lagos-Ibadan Express route (LIER) has respective of 32.53%, 32.59% and 32.59% hourly, daily and weekly freight vehicle traffic flow rates, the highest of all the three signature freight routes sampled in Lagos metropolis. This gives an average of 32.57% freight vehicle traffic flow per period on the route of the aggregate freight vehicle flow rate across all the sampled signature freight routes in Lagos metropolis. As aforementioned, this empirical information forms the basis for the development of right knowledge of approaches and strategies towards ensuring sustainable road freight and physical distribution operations on the Lagos-Ibadan Express route (LIER). The development of road infrastructure, security and safety policies to ensure sustainability of road freight operations on the route will also be based on the average freight traffic flow rates per period on the route.

Lastly, The Oshodi-Apapa route (OAER) has respective of 3.32%, 3.28% and 3.28% hourly,

daily and weekly freight vehicle traffic flow rates, the least of all the seven signature freight routes sampled in Lagos metropolis. This gives an average of 3.29% freight vehicle traffic flow per period on the route of the aggregate freight vehicle flow rate across all the sampled signature freight routes in in Lagos metropolis. Similarly, this empirical information forms the basis for the development of right knowledge of approaches and strategies towards ensuring sustainable road freight and physical distribution operations on the Oshodi-Apapa Express (route) (OAER) in Lagos metropolis. The development of road infrastructure, security and safety policies to ensure sustainability of road freight operations on the route will also be based on the average freight traffic flow rates per period on the route.

Figure 4 is a chart representation of the freight vehicular traffic per hour of the routes and a lane width per carriage way of a dual carriage way in



Source | Author (2025)

Figure 4 | Chart presentation of the number of freight vehicular traffic per hour on the freight routes and the lane width on per carriage way of a dual carriage way in Lagos.

Lagos. Based on the result presented in Table 4 which shows the pattern of the flow rate of the freight vehicles on individual signature freight routes sampled in Lagos metropolis, Table 4 is the representation of the cluster of the individual signature freight routes based on the flow rate of freight vehicles per period for the purpose of providing adequate road infrastructure for road freight operators on the individual signature freight routes in the metropolis.

The results shown in Table 4 gave important indications of the flow rates of freight vehicles on important signature freight routes in the metropolis of Lagos. The study presents patterns of freight vehicle flows on the hourly, daily and weekly time scale and offers a basis for conducting sustainable road freight and physical distribution infrastructure development and policy making. The average weekly number of freight vehicles averaged over all sampled routes is 28,153 vehicles/week with a standard deviation of 21,204.87. That meant that if freight logistics in these cities will be sustainable, the number of freight vehicles in the system should always be at or above this level ($WKFLFV_t \geq 28,153$). The study results are an average hourly flow of 167.714 vehicles/hour and an average daily flow of 4,021.857 vehicles/day, with an average SD of 125.886 and 3,029.267 vehicles/hour and daily flow respectively. For sustainability these thresholds need to be met as well ($HRFLFV_t \geq 167.714$ & $DAFLFV_t \geq 4,021.857$). It is implied that the construction of road facilities on these corridors has to be able to support these average traffic volumes without congestion or accessibility problems. Similarly, there needs to be investments in order to exceed the thresholds, which are necessary to respond to the growing demand for freight logistics services.

Further, the Lagos-Ibadan Express (LIER) route has the highest average freight vehicle traffic flow rate of 32.57% of all the routes and therefore, it should be attended to as one of the major freight routes in

Lagos metropolis. Ten percent of the routes are also special in terms of freight mobility, such as Lekki-Epe Express-Lekki (LEEP) route with 10.11%. The Oshodi-Apapa Express (OAER) route has the lowest traffic flow rate averaging 3.29%, which means that the freight traffic is relatively low on the route as compared with other routes.

The differences in freight flow patterns on routes suggest the need to develop investment and development priorities based on the specific needs of each route. Implications for Infrastructure and Policy Development: in order to prepare for the most likely flow rates, the infrastructure of the roads needs to be designed so that it can handle these flow rates, and ensure smooth freight logistics and physical distribution operations. For example, the LIER route – which has the highest flow rate – needs a lot of investment to avoid congestion and to allow freight vehicles to use the route.

The high level of traffic on LIER route, emphasises the need for safety infrastructure (lane markings, weighbridges, rest stops) and traffic regulation to prevent accidents and assure sustainable operations. The need for optimizing traffic distribution was also an important policy decision, because the large differences in traffic flow rates between the routes (e.g., LIER vs. OAER) indicated the need for policy interventions to redistribute freight traffic. This may involve, for example, rerouting and/or strengthening less-used routes, including the OAER, to make them more attractive to freight operators. The results also reveal key policy and infrastructure gaps that need to be addressed in order to facilitate sustainable road freight operations in Lagos metropolis.

For development of policies in line with the characteristic features in individual corridors and Route-Specific Infrastructure Investment. It is important for the High-traffic LIER route to have investments prioritized to accommodate existing and anticipated volumes of freight vehicles. This is

done by widening roads, adding lanes and providing auxiliary facilities (essentially parking bays, rest areas). Investments on moderate traffic routes should only be proportionate to their average traffic contributions in order to provide certain services on LEEP route. The outcomes from the thresholds applied to freight flow (hourly/daily/weekly) that have been developed as part of this study should be used as a basis for infrastructure development and upgrading. For the construction of new road facilities minimum requirements are road capacity of 167.714 vehicles/hour, 4,021.857 vehicles/day and 28,153 vehicles/week. The less congested routes (OAER and other routes) may be rewarded as part of policies that ease pressures on the highways, such as LIER. These routes can be upgraded to increase freight traffic, thus providing a balance between freight mobility in the metropolis. Increased traffic on LIER route is a concern for safety. Strict enforcement of speed limits, vehicle inspection procedures and driver training programs should be the focus of policies to increase safety.

The results are applicable to the sustainable management of road freight sector in Lagos. For instance, Freight Vehicle Registration Trends shows a medium of 3,566 new freight vehicles registered every year from 2005 to 2023, amounting to 67,760 units over the 19 years. This was the sign of good activity in an industry that was responding to greater demand for freight services but also signalled an increase in the number of freight vehicles on Lagos roads. If there is a lack of corresponding investments in road infrastructure, this situation will add to the traffic problems and prevailing road situation. Furthermore, the traffic incidents, idling time and social and economic inefficiencies are exacerbated by the increase in the number of vehicles on the roads as revealed in this which corroborates the findings of Onakomaiya, Salami, and Olanrewaju (2022).

In the case of Compliance and Non-Compliance with standards and regulations, it is found that

184,587 freight operators in the study period were in compliance with the standard and safety regulations in regards to traffic while 9,715 operators per year were in compliance. This level of compliance represents a level of freight management sustainable compliance. Road safety is improved, environmental effects are minimised and logistics are streamlined. It is also pertinent to point out that while there is a significant difference between the number of non-compliant and compliant operators in the traffic during the year, in this case 22,996 non-compliant operators annually equating to 436,933 non-compliances over the study period. The lack of compliance makes it more difficult to reach a sustainable and safe road freight sector, making road transport accidents, delays and environmental impacts more likely. The marked disparities between compliance and non-compliance rates make for an urgent need to make operators comply with the regulations and raise fines.

The study shows the following: In 19 years, there were 6,971 traffic accidents and 366.895 freight operators. The high incident rate has significant economic impacts in addition to loss of life such as damage to goods, vehicles, and infrastructure. Moreover, the high number of incidents is a step backwards towards the long-term objective of sustainable logistics and freight mobility in Lagos and this result corroborated (Ndikom, et al., 2018).

In terms of Budgetary Allocation to the Transport Sector, the total budgetary allocation to the transport sector for the period of the study was about 1.8 trillion naira while the mean allocation per year was 98.7 billion naira. This is an investment that's good for the transport sector, but the findings showed that investments have not been matched by improvements in road safety and regulatory compliance. This highlights the importance of making the best use of the available budget and focusing on projects that can solve the major issues in road freight transport

– such as infrastructure, regulatory enforcement and accident prevention.

The results of this research have policy-relevance in relation to sustainable management of the road freight sector in Lagos. The results revealed that the increasing number of the freight vehicles was a concern of a sector of Infrastructure Development and Maintenance, and it was time for immediate investment for infrastructure road for catering to the increasing number of the vehicles. Building of new roads, extending of old roads and periodic maintenance to ensure the safety of the road environment and alleviate congestion should be given more priority by the Lagos State Government. A high level of compliance with traffic rules will show the need for enhanced tools for the enforcement of traffic rules and traffic regulations for compliance and incentives. This suggests that policies should be developed to strengthen the monitoring and enforcement of traffic and safety standards, and penalties for operators that frequently fail to comply with traffic and safety standards need to be established; for example, tax breaks or reduced permit fees might be offered as an incentive for operators that are frequently compliant with traffic and safety standards. Awareness and trainings for freight operators on safety and traffic standards is also required.

In terms of the trend of traffic accidents involving freight vehicles, new measures to prevent traffic accidents may be needed to deal with the high traffic accident ratio with freight vehicles. Look at introducing compulsory freight safety training and certification, using technology-based solutions (GPS tracking, automated traffic monitoring systems and predictive maintenance equipment for freight vehicles) and designating specific freight routes, while providing bypass roads to minimise interactions between freight vehicles and other road users.

It was also determined that the huge sum of money being spent on transport should be utilized appropriately for meaningful development in transport. Policy options can range from performance audits to ensure that investments are made in projects that will make a meaningful difference to freight mobility to funding specific initiatives to improve road freight safety, or funding digital solutions to traffic management and road infrastructure investments.

The results showed that the number of new freight vehicles being registered and deployed in the Lagos metropolis for freight operations in Lagos freight corridors was decreasing with an average annual reduction of 407.23 and an intercept value of 7,638.67. This decline is a cause for concern since it may lead to future transport problems, and increased demand for road freight transport compared to supply. The reduction is not sustainable as there are planned to be more activities in the economic sector of Lagos. This is congruent with Afolabi and Gbadamosi (2017) who concluded that there is a dearth of new freight vehicles which may have a negative effect on the logistics efficiency, transportation cost and timely delivery of physical distribution products to consumers.

A policy implication is that it is beneficial to develop policies that will encourage the registration and operation of new freight vehicles. This could be tax relief, financial assistance for vehicle upgrades and subsidised registration. It also suggests that encouraging private sector investment in the freight vehicle to cater for the increasing economic demand is important for sustainable road freight operations in Lagos state and sustainable physical distribution. Improve freight vehicle replacement policies, and introduce vehicle replacement schemes to replace less efficient and old trucks, helping to keep the sector competitive and sustainable.

The involvement of road freight vehicles in road traffic accidents (RTA) has been on the decline over the years, on average 58.77 accidents per year and intercept 954.614. The decrease in traffic accidents is a positive step towards the sustainability of road freight operations in Lagos. The reduction of accidents leads to reduction of socio-economic cost of accidents such as loss of human life, injuries, damage to property, traffic delays etc.

The study also revealed that the operators of road freight transportation are not enforcing the traffic rules; the average number of incidents of non-compliance per year was 3,612.446 while the average intercept value was -13,127.982. This situation is a significant risk for the sustainability of road freight transport as it can lead to traffic jams, accidents and inefficiency in freight transportation. It also hampers efforts to establish a safe and orderly transport environment in Lagos.

The study shows that the budget allocation for the transport sector increased with time with a range of annual increase of ₦8,678,217,722.45 and an intercept value of ₦12,011,017,922.81. The up-gradation of budget allocation is certainly a positive sign of the government's commitment to address the issues in the transportation sector. But the results indicated these programmes are not yet delivering the best results in other areas such as infrastructure improvements and regulatory oversight. Key policy implications include prioritizing investments in areas with the highest potential impact on roads, such as road infrastructure development, extension of freight road networks, safety initiatives and transparency and accountability in fund usage for maximum impact. And the need to build public-private partnerships to complement government funding and to speed up project delivery. Comprehensive data collection tools are needed to monitor compliance and traffic accident trends, as well as vehicle deployment trends, to improve the effectiveness of policy.

5. | Conclusion

After implementing the analysis of the data collected for this study and discussed above based on the study goals, the study therefore concludes as follows:

The results do not only reiterate the need for a comprehensive and sustainable road freight policy to address the challenges currently faced by the road freight sector in Lagos, but they also point to the necessity to look at the sector as a whole for solutions. In order to ensure long-term sustainability in freight mobility in Lagos Metropolis, strategic investments in infrastructure, effective regulation actions and focused interventions to reduce traffic accidents are required. The outcomes will be disseminated in the form of empirical evidence to facilitate the decision making process of the policy makers, stakeholders and industry leaders in the direction of sustainable freight distribution patterns in Lagos State.

The results from the rate of change analysis provide hand-on answers to the tendencies in the road freight industry in Lagos Metropolis. Sustainable freight operations are indicated by positive trends like reduction in traffic accidents and increase in compliance, whereas negative trends like reduction in vehicle registrations and increase in non-compliance rates indicate challenges that need immediate attention. Negative trends should be reversed, positive trends should be kept going and budgets allocated should be made to have a real impact in the sector in terms of strategic policies. By addressing the issues raised above, Lagos can reach a more efficient and sustainable road freight logistics system that is able to satisfy the increasing economic demands.

Periodic traffic flow rate of freight vehicles in Lagos corridors has yielded a strong framework of understanding of freight vehicle flow patterns,

and what they mean for infrastructure and policy development in Lagos metropolis. Sustainable logistics policy, through investments in high traffic routes, safety policy and compliance can assure efficient freight logistics and help to sustain road transport in the region of Lagos State. The results also identify the need for continued monitoring and analysis to adjust to evolving freight traffic requirements.

Lastly, in the case of road freight corridors in the Lagos metropolis, the study's results highlight the importance of the need for upgrading of the infrastructure in road freight corridors in the Lagos metropolis. There are many routes that are not enjoyable due to road conditions, and others, like LEEP route highlight lack of width of lanes. The potential issues should be taken into account by the policymaker, and in most cases, lane additions should be considered over rehabilitation. The rehabilitation and improvement of the road freight logistics system in Lagos can contribute to the sustainability and efficiency of the road freight sector, ensuring the transport system is more functional and reliable in the future.

6. | Recommendations

Based on the above, the following recommendations are made in the study:

- i. Authorities and operators should pursue further implementation of road safety policies and strategies to continue the downtrend in accidents.
- ii. Investment in driver training courses and a requirement for freight vehicle operators to be certified.
- iii. Expansion and continued maintenance policies provided for freight routes distinguished freight vehicles from general traffic to minimize the risk of accidents.
- iv. Encourage the use of technology including telematics and real-time tracking to improve driver behaviour and minimise collisions.
- v. Creating multimodal logistics centres to lessen road freight dependence.
- vi. Including freight in urban planning and land-use policies.
- vii. Public-Private Collaboration. To achieve sustainable freight distribution in Lagos, collaboration between the government and private road freight operators is essential especially with regards to funding transport infrastructure and intervention projects such as safety programs, and introduce technology-driven solutions.

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