Cumulative Damage Effects of Truck Overloads on Nigerian Road Pavement

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Abstract- **Road infrastructure is one of the basic facilities needed for the growth and advancement of any modern economy. The growth of every country's economy is measured by the growth of it's transport infrastructure. This is very true of Nigeria as the state of failed roads all over nation gives a clear picture of the situation of the economy. The road network system has so failed that travelling within any part of Nigeria has turned to be the most assiduous venture for the citizens to undertake. For these reasons, this research examines the devastating effects of truck overloads on the road pavement failure in Nigeria. This research analyses the axle loads of heavy vehicles on Lagos-Ibadan Expressway to see how they influence the state of the road's pavement condition. The expected pavement load was quantified through equivalent single axle loads (ESALs). Analysis of the data resulted in the existence of high vehicle damage factors caused by overloaded heavy vehicles.**

Index Term-- **Road Pavements, Truck Overloads, Damages.**

1. INTRODUCTION

Road infrastructure is one of the basic facilities needed for the development and growth of any modern economy. The growth of every country's economy is measured by the growth of the transport infrastructure in the country. No wonder the beauty of the advanced nations' economies can be quickly measured by the beauty of their transport facilities, while the stunted economy of the under-developed nations is easily visible in their pot-holed infrastructural system (Ede and Oshiga, 2014). This is why a foreigner from any advanced nation on visit to Nigeria will not need to ask anyone about the state of Nigerian economy after plying some few kilometres of Nigerian roads.

The level of provision of good and efficient road network spread in a nation defines the level of mobility of persons, goods and services within that country: more efficient the transport system, more prosperous the nation's economy. This is one of the principle factors that have made the development of tourism a very lucrative source of earning in nations that run well coordinated and more rational approach to the provision and maintenance of transport systems.

Because of the importance of the provision of these facilities to the economy and the high cost involved, the onus for providing such facilities lies on the government. The management of the transport facilities can be through government departments or in collaboration with the private sector.

Over the years, the Nigerian government has spent huge sums of money in the development of road infrastructure. Nigeria has the highest number of developed road network system in Africa estimated to cover over 200,000 kilometres (World Bank report, 2009). But the usefulness of these roads has been drastically reduced due to poor maintenance culture. The decadence of the Nigerian roads emanates from poor designs and untidy execution of the road projects. This is mostly typified in the provision of inadequate drainage system that gives rise to potholes, erosion of the roads and other avoidable defects that continue to destroy the road network systems. These problems translate to high cost of goods and services, high death rate due to fatal accidents on the bad roads and the high loss of man-hour in traffic. Ultimately, these culminate into a vicious cycle of hyper-cost of production, low productivity, escalating inflation, unemployment and a stagnating economy. No wonder Nigeria is gradually becoming one of the most costly nations to live in on the face of the earth.

For these reasons, this article examines the effects of heavy vehicular overloads on the road pavement failure in Nigeria. This paper considers the status of road infrastructural decay in Nigeria and analyses data on the state of Lagos-Ibadan Expressway.

2. ROAD INFRASTRUCTURAL DECAY IN NIGERIA

The construction of modern roads in Nigeria is as old as the colonial administration in Nigeria. The initial focus was to connect the administrative centres and subsequently to connect some economic centres of their interest. Initially the quality of roads was very poor. But as the network and length of roads increased, the design and qualities improved (CBN report, 2003). Currently, the Nigerian road network system is estimated to cover about 200,000 Kilometres (World Bank Report, 2009).

Currently, the Nigerian roads are grouped under three categories: the trunk A roads under the ownership of the Federal Government, trunk B under the care of the State Governments, and trunk C belonging to the Local Governments. It is the duty of each government to fund, construct and maintain the network of road infrastructures within its jurisdiction. The estimated distribution of the road network system in Nigeria is as follows: 17%, 16% and 67% respectively for the Federal, State and Local governments.

The current state of road infrastructural decay in Nigeria is related to the poor road maintenance culture obtainable in the country. Good road maintenance helps to retain a road in an optimal state that guarantees an optimal utilization as was envisaged in the design and prevents the development of other defects. As long as roads are being maintained, they will remain useful and can be upgraded to meet the changing needs of the people. Roads in good shape reduce the operational cost of vehicles; ensure punctuality in transport service delivery and guarantees safety of persons and goods. All these contribute to reduce the cost of doing business, improve productivity thereby bringing about a sustainable growth of an economy. In Nigeria, the state of roads is very pathetic, such that it remains one of the major factors pulling Nigeria backwards from sustainable economic growth.

Generally, highway repairs can be classified into programmed maintenance (more frequent periodic maintenance or less frequent periodic maintenance) and emergency maintenance. Programmed maintenance are planned to take place over different periods of time. The more frequent periodic maintenance is meant to keep the road in a good shape for normal usage by correcting minor defects that develop over time such as potholes, drainage clearance etc. If these minor defects are not corrected on time, they metamorphous to major challenges that could lead to total disruption of traffic on the road. The less frequent periodic maintenance aims at carrying out major repairs and rehabilitations on the road such as maintenance of the pavements, surface dressing, shoulder gravelling etc. The programming of these repairs is influence by a lot of factors such as environmental and climatic characteristic of the area and the stresses generated on the road by the volume of traffic. The planning of the repairs evolves over time as data are frequently collected and upgraded by a monitoring group.

The emergency maintenance is carried without programming as the needs arise. Any time the unexpected occurs such as flooding, substantial landslide, earth quake or any other environmental disaster that creates situation that is capable of disrupting traffic flow on the road, emergency repairs is carried out to restore flow of traffic on the road.

The maintenance of Nigerian roads today leaves a lot to be desired. It is very difficult to understand the rationale for road maintenance in Nigeria. Major roads in Nigeria such as Apapa - Oshodi express way, Lagos – Ibadan expressway, Shagamu – Benin express ways, just to mention a few have been permanently in emergency conditions for years and there seems to be no corresponding emergency efforts to put then in order at least for their importance to the economy of the nation. In fact, the poor maintenance culture seems to be more visible in road infrastructural sector than any other sector.

The poor state of Nigerian roads can be traced to a number of reasons. Faulty design and poor construction remains the fundamental cause of the bad state of Nigerian roads. Poor drainage system causes water to percolate on the road for a long time thereby weakening the road and making room for the birth of potholes. Closely related to the issue of poor drainage is the construction of flat and irregular road surfaces that does not make provision for water to be drained off the road.

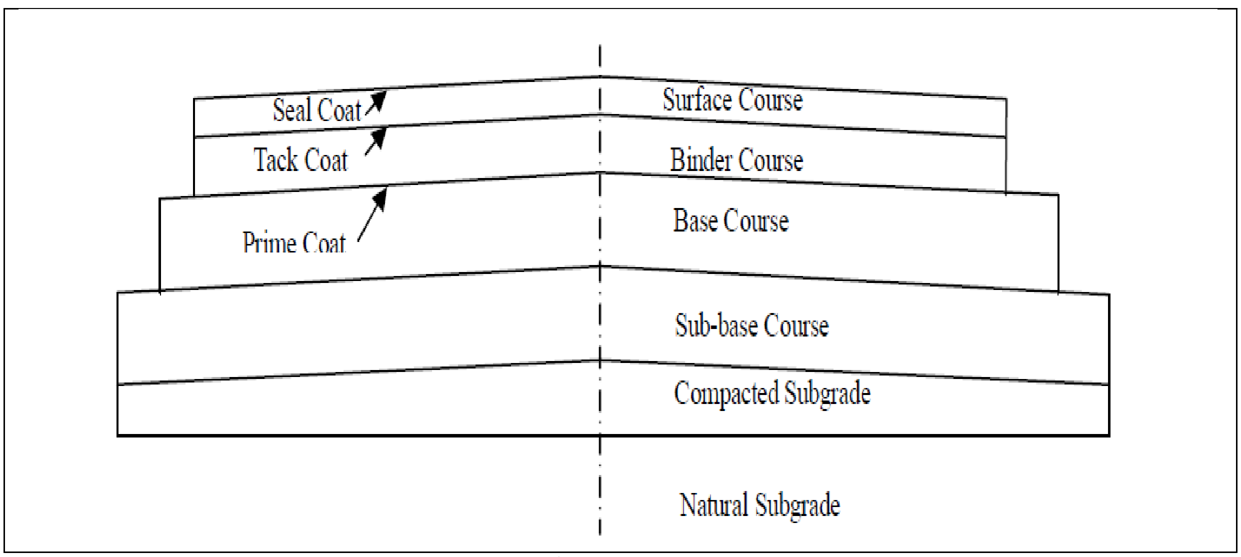

Fig. 1. Typical cross section of a conventional good road; Source: (Huang, 2004)

The centres of the roads are supposed to be fairly higher to cause water to flow out, but such is seldom the case in most of the roads. The permanence of water on the road is the principle cause of potholes. Figure 1 shows a section good road. The dominance of foreign firms in the road construction industry in Nigeria is does not help the matter. Most of the roads are designed and constructed by foreign firms without adequate provision for future maintenance. Because of the poor academic curriculum and the scarcity of qualified professionals in the road construction, most of the repairs and rehabilitations end up in the hands of incompetent companies that do shabby works that contribute to the deterioration of the state of the roads.

Another important cause of the bad state of Nigerian roads is the excessive stresses on the road networks. Most of the important road networks in Nigeria were built over 30 years ago. Since then the Nigerian population has more than doubled and the number of vehicles on the roads have multiplied exponentially. Moreover, the road network is the only developed mode for the haulage bulky goods in the country.

Another factor contributing to the bad state of Nigerian roads is the issue of funding. The fact that all the fund for the repairs of all the roads has to come from the Government is strictly not a laudable approach. The nation is faced with myriad of problems in every sector of the society coupled with the very high cost of running the three tiers of government. All these affect the maintenance of the very many road networks in the country. Still on the issue of funding, the disruption of maintenance work due to non payment of contractors because of inadequate fund is another common feature in the road maintenance works in Nigeria. Often the stage at which these contracts are abandoned are so critical such that at the time when the fund is made available for the contractor or the contract rewarded, the work already executed before the disruption will be of depreciated value to the execution of the whole project, thereby making the projects very expensive.

3. BEHAVIOUR OF ROADS UNDER LOADS

3.1 Characteristic of road pavement design

The origin of road construction can be traced to the Roman Empire. The approach to road design has essentially remained the same as the roads were constructed of several different layers, increasing in strength from the bottom. The thickness of the layers was varied according to the local ground conditions (Toll, 1997).

After the selection of the appropriate type of pavement required and the design life, the traffic for design is estimated. Research has shown that the loads imposed by commercial vehicles with unladen weight exceeding 1500kg and their axle loadings are considered for design.

The road pavement provides traction for vehicles to travel as well as transfer normal stresses from the vehicle to the underlying soils (sub-grade). The pavement reduces the stresses on the sub-grade to such a level that the sub-grade does not deform under the action of traffic (Rolt, 2004). The condition of the road will slowly deteriorate with time, traffic loads and environment.

As the primary functions of a pavement is load redistribution, representative loading characteristics must be presumed about the expected traffic it will encounter in order to adequately design a pavement. Vehicular loads exerted on the pavements can be characterized by the following parameters: tire loads, axle and tire configurations, typical axle load limits, repetitions of axle loads and traffic projections or growth rate.

The effects of loads on pavements are assumed on the basis that each individual load inflicts a certain amount of irrecoverable damage on the pavement. This damage is cumulative over the life of the pavement and when it reaches some maximum value, the pavement is considered to have reached the end of its useful service life. Figure 2 shows the distribution of wheel load along the layers of the pavement with the most superior material being at the topmost layer.

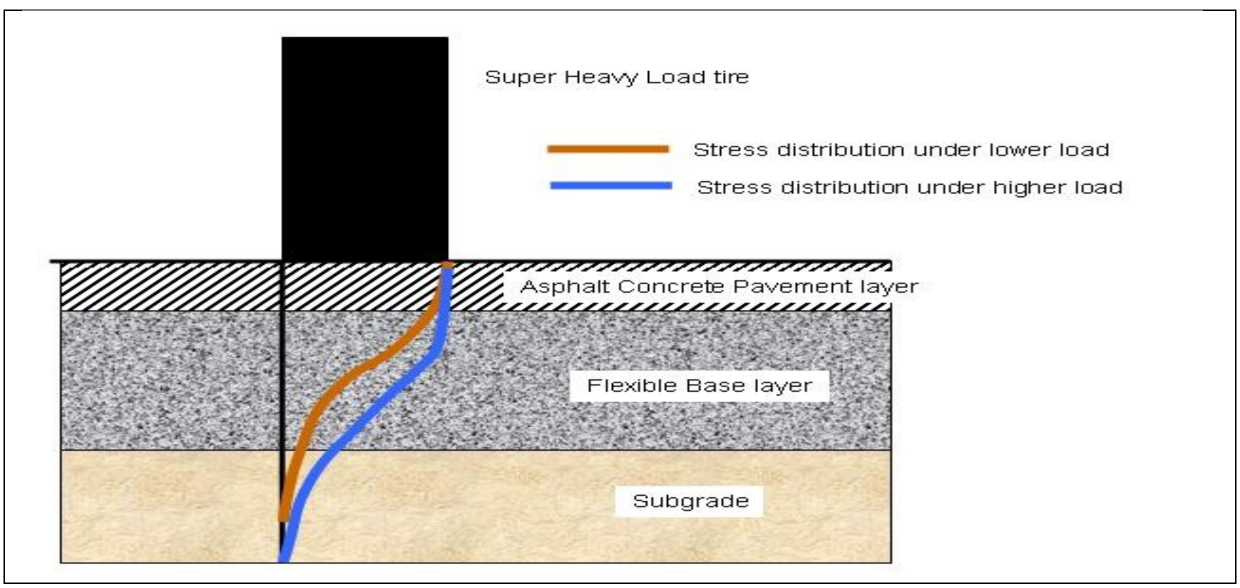

Fig. 2. Stress distribution on a road pavement Source: Una (2011)

Pavement structural design and maintenance requires a quantification of all expected loads a pavement will encounter over its design life. This quantification can be done through the equivalent single axle loads (ESALs). This approach converts axle configurations and axle loads of various magnitudes and repetitions to an equivalent number of standard loads. The standard axle is given as 80 KN.

Pavement structure is typically composed of several layers of materials. Each layer receives loads from the above layer, spreads them out, and passes on these loads to the next layer below. Thus the stresses which are maximum at the top layer will reduce on the top of sub-grade. In order to take maximum advantage of this property, layers are usually arranged in the order of descending load bearing capacity with the highest load bearing capacity material (and most expensive) on the top and the lowest load bearing capacity material (and least expensive) on the bottom (Mathew and Rao, 2006). This principle makes it possible to use local materials and usually results in a most economical design (Huang, 2004).

Figure 1 shows the cross section of a conventional pavement. Starting from the top, the pavement consists of friction course (seal coat), surface course, binder course, base course, sub-base course, compacted sub-grade (capping layer) and natural sub-grade. The use of the various courses is based on either necessity or economy, and some of the courses may be omitted.

The materials for the wearing course are made up of hot rolled asphalt (HRA) and must have a good fatigue resistance.

The base course is constructed with any of the following materials: dense bitumen macadam (DBM), hot rolled asphalt (HRA), high density macadam (HDM) together with a wide range of unbound materials which include crushed quarried rock, crushed and screened, mechanically stabilized, modified or naturally occurring `as dug' gravels. Their suitability for use depends primarily on the design traffic level of the pavement and climate but all road base materials must have a particle size distribution and particle shape which provide high mechanical stability and should contain sufficient fines (amount of material passing the 0.425 mm sieve) to produce a dense material when compacted. The final choice should take into account the expected level of future maintenance and the total costs over the expected life of the pavement.

The sub-base is an important load spreading layer in the completed pavement. It enables traffic stresses to be reduced to acceptable levels in the sub-grade, it acts as a working platform for the construction of the upper pavement layers and it acts as a separation layer between sub-grade and road base (base course). Under special circumstances it may also act as a filter or as a drainage layer. In wet climatic conditions, the most stringent requirements are dictated by the need to support construction traffic and paving equipment. In these circumstances the sub-base material needs to be more tightly specified. The selection of sub-base materials will always depend on the design function of the layer and the anticipated moisture regime, both in service and at construction. For the bearing capacity, a minimum CBR of 30 per cent is required at the highest anticipated moisture content when compacted to the specified field density. In order to achieve the required bearing capacity, and for uniform support to be provided to the upper pavement, limits on soil plasticity and particle size distribution may be required.

Subgrade is the upper layer of the natural soil which may be undisturbed local material or may be soil excavated elsewhere and placed as fill. In either case it is compacted during construction to give added strength. The strength of the sub-grade is assessed in terms of the California Bearing Ratio (CBR) and this is dependent on the type of soil, its density, and its moisture content. To estimate the design sub-grade strength, it is first necessary to estimate the design moisture content of the sub-grade. Compaction will not only improve the sub-grade bearing strength but will reduce permeability and subsequent compaction by traffic.

One of the three main steps suggested to be followed in designing a new road pavement and which is extremely vital for the planning of road maintenance (ORN 31, 1970) is the estimation of the amount of traffic and the cumulative number of equivalent standard axles that will use the road over the selected design life.

3.2 Deteriorating state of Nigerian roads

Several factors are responsible for the failure on Nigerian road and they include geotechnical properties of the soil, topography and drainage, climate, geology, poor design, poor construction materials and poor construction technologies (Osadebe and Omange, 2005). The near absence of other modes of transportation in Nigeria has put so much pressure on Nigerian roads as it remains the only mode for the movement of heavy duty loads. This has significant damaging effects on the roads. It is the pressure of heavy duty loads on the roads that necessitated this research. This research aims to provide insight on the impacts of overloads on the deterioration of Nigerian roads and to proffer solutions on how to accommodate the growing numbers of heavy loads moving from one part of the nation to the other.

The research involved the analysis of axle loads of heavy vehicles on Lagos- Ibadan Expressway and how they influence the state of our roads.

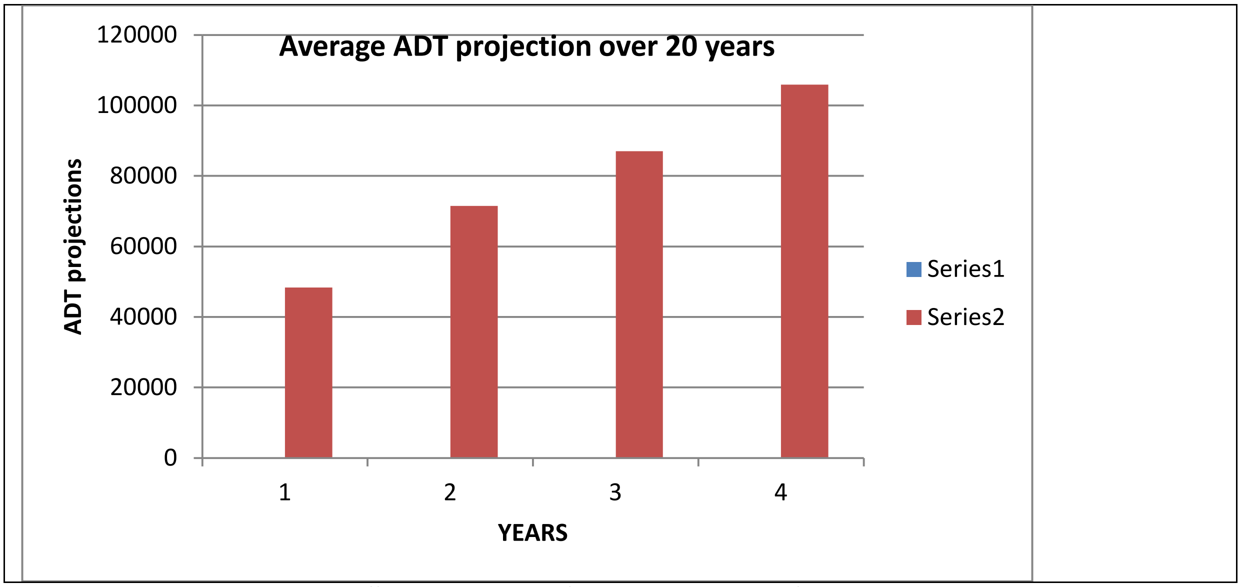

Fig. 3. Average Daily Traffic (ADT) projections for Lagos – Shagamu axis from 2009 to 2019, 2024 and 2029.

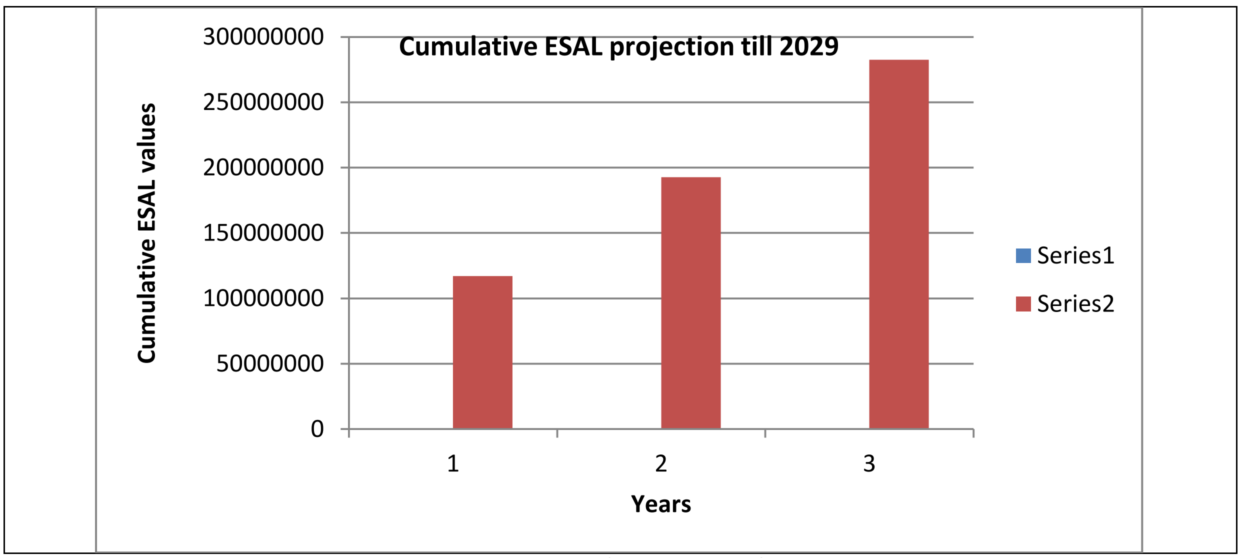

Fig. 4. Cumulative ESAL Projections of the heavier axis for 2019, 2024 and 2029.

4. DATA ANALYSES AND RESULTS

4.1 Material and method

This research analyses the traffic trend of heavy duty trucks on Lagos-Ibadan expressway in search of determining the impact of overloaded trucks on Nigerian roads and to suggest ways of reducing the excessive heavy traffic stress.

The Lagos–Ibadan Expressway was constructed between 1976 and 1979. The carriage way has undergone various levels of deterioration over the years since it was built and opened to traffic. Presently, the pavement is in a dilapidated state (Bi-Courtney 2010).

The study was based on data obtained from the archives of the Federal Ministry of Works and Housing and Urban Development as collated by Bi-Courtney Highway Services Limited (Bi-Courtney 2010) and from (Una, 2011). Statistically analysis was applied for predictions of results.

4.2 Analysis of results

Data collected were used to calculate the mean number of equivalent standard axles (ESAL) for a typical vehicle in each class and to determine the predicted cumulative equivalent standard axles that the road will carry over its design life.

Analyses of the data gave the average percentage of heavy vehicles on the expressway as 13.5% in 1998.

From the 24hr average daily traffic (ADT) versus the daily heavy vehicles for both Ibadan bound and Lagos bound and their percentage constitution, the current average percentage of heavy vehicles on the road was determined to be 18.41%. This shows a high growth rate when compared to an average percentage heavy of 13.5% recorded on the same road in 1998.

Starting from an average daily traffic (ADT) of 48311 vehicles per day (vpd) for the Lagos – Shagamu axis in 2009, the traffic projections over 20 years at 4% growth rate on the same axis stand as 71513 for 2019, 87006 for 2024 and 105856 for 2029. This is shown in figure 3.

The volume of daily heavy vehicles was used to calculate the ESAL for the base year (2009) and the cumulative ESAL projections for 20 years. The ESAL was determined to be 34,199 in the heavier direction while the cumulative ESAL projections over 20 years stand at 117138497 for 2019, 192734270 for 2024 and 282410630 for 2029 at a 4% growth rate. The cumulative ESAL is shown in figure 4.

Axle load measurement data collated were used to determine the Gross Vehicle Mass (GVM) and the Vehicle Damage Factor (VDF). From these data, an average VDF per truck of 11.12 and 9.39 were obtained for the Ibadan bound and Lagos bound directions respectively.

5. CONCLUSION AND RECOMMENDATION

The axle load measurement showed that most of the heavy vehicles were overloaded resulting in high vehicle damage factors of up to 11.12 and 9.39 for the North-bound and South-bound vehicles respectively. .

The trend of growth of vehicles determined from the historic traffic data analyzed showed a high growth rate in the percentage of heavy duty vehicles from 13.5% to 18.41% between 1998 and 2009.

All these findings point to the excessive traffic stress that is being put on the road by heavy duty vehicles and their overloads. The level of stress on other Nigerian roads will not be much different from this. The following recommendations are therefore made:

- That the road repairs operations in Nigeria must depart from the poor maintenance culture that is visible in every sector of economy to save the nation's economy from continuous stagnation.
- More regular monitoring should take place on this road and other Nigerian roads to determine the state of the roads and intervene promptly with the maintenance when due. This will save the nation from costly repairs that hardly last within this Nigerian peculiar ecological and environmental sub-region.
- It is recommended that other modes of transportation such as water ways and railways be vigorously improved upon. This will save Nigerian roads from the rising level of overloaded heavy duty freight trucks as this research high-lightened.
- For the excess damage factors verified on this road due to overloads, it is time to start enforcing the legal axle loading for heavy trucks. This can be done using weigh bridges at toll station and defaulting drivers should be heavily fined to curb the trend. The reintroduction of toll gates as just approved by the Federal Government will help to monitor and checkmate the issue of overloads on Nigerian roads.

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