THAT WE MAY NOT OVERTAKE DEATH: TOWARDS A SUSTAINABLE ROAD INFRASTRUCTURE DEVELOPMENT

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1. Preamble

Mr. Vice Chancellor Sir, distinguished ladies and gentlemen, it is with deep sense of humility and gratitude to Allah subuhanatala, that I stand here today to present my inaugural lecture: **'THAT WE MAY NOT OVERTAKE DEATH: TOWARDS A SUSTAINABLE ROAD INFRASTRUCTURE DEVELOPMENT'**, the 414th in the series of inaugural lectures of this University, and the second of such from the Department of Civil Engineering – the first was delivered twenty-nine years ago.

Mr. Vice Chancellor, distinguished guests, I am a latter day academic. I joined the academics in 2008, as Lecturer I at the Epe campus of Lagos State University. This was twenty-six years after I obtained my first degree from University of Ife (now Obafemi Awolowo University, Ile-Ife). I later joined Obafemi Awolowo University, also as Lecturer I on August 4, 2010. My foray into academics is quite interesting, I started my engineering practice after the mandatory National Youth Service in 1983 at the University of Ife as a Resident Engineer. In 1992, I resigned from my job as Resident Engineer and decided to engage in private engineering practice as a Contractor. I opted for the '90 %' as against the '10 %' that Contractors will want to offer as tips to government employees. I discovered much later in my sojourn in private practice that, it was easier to get the '10 %' as a government employee than the '90 %'. So, my travail started.

My wife suggested that in view of my inability to play the 'game', I should consider returning to school for further studies. I chose this option and obtained my M.Sc. and Ph.D. degrees from University of Ibadan in the year 2004 and 2010, respectively. It became easier for me to move to the academics as I believed and still believe, that teaching in the University, is probably the *sanest* thing to do. In the University, there is a choice of being honest without adverse consequence.

In the fifteen years that I have worked as an academic in the Department of Civil Engineering, Obafemi Awolowo University, Ile-Ife, I rose through ranks to become a Professor of Civil Engineering in 2021. I had the opportunity to serve as the Acting Head, Department from 2014 and 2017. I served as a member of several Committees in the University namely - Review Panel for the Division of Works and Maintenance Services, (2011); OAU New Town Development Authority, (2012); Technical Committee on NUGA projects, (2013); Task Force on Rehabilitation of Students' Hostels, (2014); OAU Traffic Light Restoration and Maintenance, (2022); Roads and Traffic Monitoring, (2023) and Obafemi Awolowo University, New Shuttle Transport Committee, (2025, to date). I also served as the Chairman, Committee on University Transport, in the year 2024. My service on these Committees offered fulfilling and enriching experience within the University system.

Mr. Vice Chancellor, Sir, my academic forays have been in Transportation Engineering. This was borne out of practice incident, when I was engaged as one of the resource personnel in a regional transportation master plan in Nigeria, in 2000. At that time, the enquiries made in many Universities across Nigeria revealed that there were no sufficient experts in transportation engineering that could be recruited for the task ahead. This revelation sparked an interest to address this gap by training to become an expert in transportation engineering, and also train others to fill the gap created by the dearth of experts in transportation engineering in Nigeria.

2. Introduction

Infrastructure is a generic term for basic structures and facilities that are essential to the generation of economic growth and development in modern economies. It covers many facilities generally referred to as economic and social overhead capital which include education, water supply, sewage systems, energy, postal and telecommunication services, hospitals, and transport systems; especially the roads. Efficient provision of infrastructure is usually characterized by heavy capital outlay, indivisibility of benefits and high externalities. In view of these properties, government is usually called upon to provide such facilities especially in the developing economies. In countries where the development of these infrastructures has followed rational, coordinated and harmonized path, growth has received a big boost. This is because infrastructure provision and development serve as input into private sector production, thus facilitating output growth and productivity; Japan and South Korea are examples of countries that embraced massive infrastructure provision to turn around their economic fortune. On the other hand, where the growth of infrastructure has not followed such a harmonized path, development is usually stunted as exemplified by most African countries and other Less Developed Countries (LDCs). The provision of infrastructure can be achieved through; (i) public ownership with private sector management and operations, (ii) public ownership and operation through public enterprises or government departments, and (iii) private ownership/operation and community provisioning. The provision of infrastructure in Nigeria is characterized by the predominance of public enterprises (Anyanwu, Adebusuyi, and Kukah, 2003).

3. Transportation System

Transportation system consists of fixed facilities, the flow entities and the control system that permits people and goods to overcome the friction of geographical space efficiently in order to participate in a timely manner in some desired activity. The functional components of a transportation system - the fixed facilities, the flow entities and the control system; encapsulates the fact that transportation provides the connectivity that facilitates other societal interaction. Fixed facilities connote the physical components of the transportation system that are fixed in space and constitute the network links (e.g. roadway, railway track etc.) and nodes (intersections, interchanges, transits terminals, harbours, and airports) of the transportation system. Their design, which has traditionally been within the realm of civil engineering, includes soil and foundation engineering, structural design, the design of drainage systems, and geometric design; which is concerned with the physical proportioning of the elements of fixed facilities. Flow entities are the units that traverse the fixed facilities. These include vehicles, container units, railroad cars etc. The control system consists of vehicular control and flow control. Vehicular control refers to the technological way in which individual vehicles are guided on the fixed facilities. Such control can be manual or automated. The proper geometric design of the fixed facilities must incorporate in addition to the characteristics of the vehicle; the characteristics of the vehicular control system. In the case of highway facilities, where the vehicles are manually controlled, these include driver characteristics, such as the time a driver takes to perceive and react to various stimuli. The flow control system consists of the means that permit the efficient and smooth operation of streams of vehicles and the reduction of conflicts between vehicles. This system includes various types of sign, marking and signal systems and the concomitant rules of operation. A transportation system provides the necessary connectivity that enhances the interaction between people. It is a historical fact that by facilitating the movement of peoples and the spreading of ideas, advances in transportation technology have been closely related to the evolution of civilization. Since ancient times, cities have developed in location that took advantage of the availability of transportation connection. The Roman Empire was held together by a very elaborate system of roadways, some of which (e.g. the Appian way) remain at the present (Papacostas,1987).

Transportation systems constitute a potent force in shaping the course of regional development. Transportation, which encompasses a broad range of policy variables along with the planning and development of transportation facilities, plays a vital role in improving living standards and enhancing the aggregate values of communities (Khisty, Jotin, & Lall, 1990). Transportation contributes to the economic, industrial and cultural development of a country. The importance of transportation to a country is comparable to the veins in the human body. Just as veins in the human body maintain health by circulation of blood to different parts of the body, similarly means of transportation keep the health of a nation in good condition by keeping goods and people moving from one place to another. Thus, transportation is vital for the all-round development of a nation, or region, since every commodity needs transport facilities both at the production stage as well as distribution stage. Thus, for the economic, cultural and social development of a country an effective and adequate system of transportation is essential (Garber & Hoel, 2015). Transportation is a critical function for an economy as it affects the movement of people, goods and services, and development (Nelson, 2000).

Transport is recognized as fulfilling four primary functions that facilitate economic development. First, it is an obvious factor input into the production process permitting goods and people to be transferred between and within production and consumption centers. Given that the majority of this movement takes place between rural and urban areas, it facilitates the integration of the monetary economy within the agricultural sector. Second, transport enhancements have the potential to shift the production possibilities frontier through their impact on factor costs, notably by lowering the inventory held within the production process. Third, factor mobility is increased permitting factors of production, especially labour to be transported to places where they may be employed most productively. Finally, transport increases the welfare of individuals by extending the range of social facilities to them, and also provides superior public goods given as greater social cohesion and increased national defense (Onwioduokit, 2000).

Mr. Vice Chancellor sir, the significance of transport to the development of a country lies in the fundamental fact that mobility and accessibility are essential for economic growth. For instance, transport allows accessibility to agricultural lands, health, education, employment, commence, mineral resource base, and forest industries in community. The transport sector is therefore the basic service sector to the other sectors of a nation's economy; hence, it is usually referred to as the actor and connector sector (Akinbami and Fadare, 1997).

4. Road Infrastructure in Nigeria

Road infrastructure development in Nigeria, can be viewed along some of the headings discussed thus:

4.1 History of Highways

Highway art is one of oldest known art to man. The earliest roads evolved from primitive tracks created by humans and animals, which gradually formed recognizable footpaths. These footpaths typically represented the most direct and convenient routes to essential destinations, such as fishing and hunting grounds. These paths created by humans and animals; naturally followed lines of least resistance, avoiding steep gradients, wetlands, and other natural obstacles. If a river has to be crossed, the trail either detoured to affordable location or fallen trees used as bridges across the river. The development of the wheel at about 3500 BC created a significant technical progression and greatly accelerated the development of highway construction. The possibility of carrying greater loads on wheels was concomitant to improvement in carriageway development. On the Island of Crete in the Mediterranean Sea, archaeologists discovered a stone-surfaced road constructed by the Minoan civilization, dating to approximately 2000–1500 BC. Road construction also received extensive consideration during the Roman Empire. The Roman empire was held together with an extensive system of roads which were required by the traders and for movement of the Roman legion (Oguara, 2006).

4.2 Highway Development in Nigeria

Highway construction commenced in Nigeria at the beginning of the twentieth century. The first sets include, Calabar to Obubra and Oron to Onitsha, in the East; Ibadan to Oyo, Osogbo to Ilesha and Ogbomosho, in the West and Zungeru to Zaira cart road in the North. Others include, Lagos to Ibadan, Benin to Sapele, Ijebu-Ode to Ibadan and Abeokuta, Enugu to Port Harcourt, Sokoto to Zaira and Kano to Katsina (Oguara, 2006).

According to the Nigeria Road Safety Strategy (NRSS, 2012–2016), the total road length in Nigeria is approximately 194,000 km, comprising 34,120 km of federal roads, 30,500 km of state roads, and 129,580 km of local roads, spread over a land area of 910,771 km² (Federal Road Safety Corps [FRSC], 2012). About 4% of the total network, largely consisting of federal roads, is classified as critical corridors due to their strategic importance for inter-regional connectivity. This corresponds to a road density of approximately 21 km per 100 km². The road map of Nigeria is as shown on Plate 1.

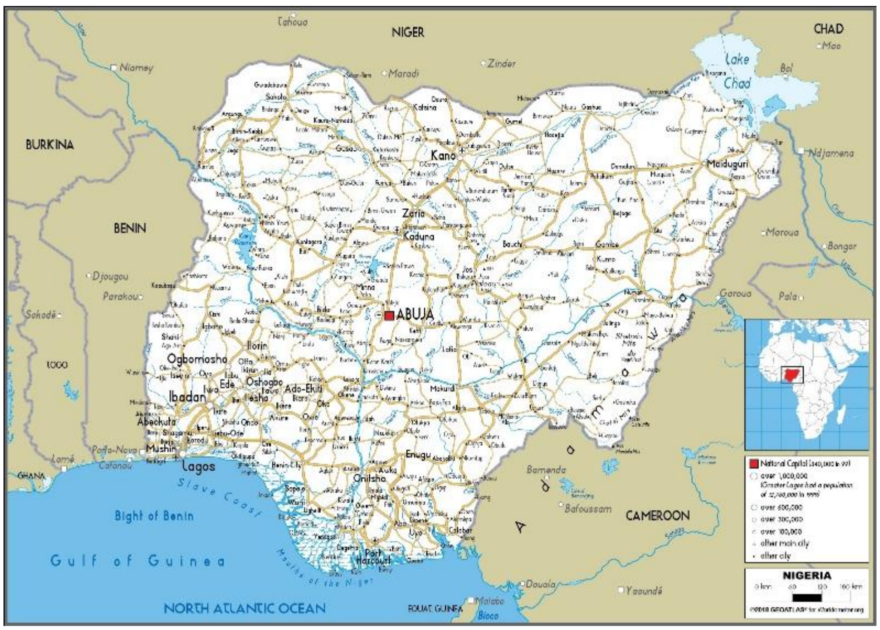


Plate 1: Road Map of Nigeria

Currently, Nigeria has about 196,000 km road network, 34,341 km (17%) are Federal roads; 30,500 km (16%) are State roads; and the remaining 130,600 km (67%) are Local Government/ Local Council Development Authority roads (Abiodun, 2013; Campbell, 2009; Oni & Okanlawon, 2006; Central Bank of Nigeria, 2003). Barely 28,980 kilometers (15 %) of the total length of roads is paved; while 70 % of the paved roads are not motorable due to lack of maintenance (Oyedele, 2019). Table 1 shows the road network distribution.

The Nigerian Road system is classified into trunks 'A', 'B' and 'C'. Trunk 'A' roads are constructed, managed and owned by the Federal Government, trunk 'B' roads are developed, maintained and owned by the states and trunk 'C' roads are under the ownership and management of the local governments (Adetola et al., 2011). The distribution the Trunk 'A' roads in the six geo-political zones of the country is as shown in Table 2.

Table 1: Distribution of National Road Network in Nigeria

Type of Pavement	Federal (km)	State (km)	Local Government (km)	Road Network (km)
Paved Trunk Roads	28,741	10,400	-	39,141
Unpaved Trunk Roads	5,600	20,100	-	25,700
Urban Roads	-	-	21,900	21 ,900
Main Rural Roads	-	-	72,800	72,800
Village Access Roads	-	-	35,900	35,900
Total (km)	34,341	30,500	130,600	195,441
Percentage	17%	16%	67%	100%

Source: Oni and Okanlawon, 2006

Table 2: Federal Highway Network in the Six- Geo-Political Zones of Nigeria

Zone	States	Road Network (km)
South-East	Anambra, Enugu, Imo, Ebonyi, Abia	3,121.70
South-West	Lagos, Osun, Oyo, Ondo, Ekiti, Ogun	4,161.06
South-South	Akwa Ibom, Delta, Cross River, Bayelsa, Rivers, Edo	4,150.89
North-East	Adamawa, Bauchi, Borno, Gombe, Taraba, Yobe	6,787.90
North- West	Kaduna, Jigawa, Kano, Katsina, Kebbi, Sokoto, Zamfara	6,363.40
North-Central	Niger, Kwara, Plateau, Benue, Nasarawa, Kogi, Federal Capital Territory Abuja	9,756.00
Total		34,340.95

Source: Adetola et al., 2011

5. Road Infrastructure and Sustainable Development

Sustainable development in its intent and purpose, advocates living today and ensuring a safe navigation for future generation. On this premise road infrastructure development should be concomitant with sustainability.

Mudasiru (2025) remarked that transportation infrastructure serves as the literal and figurative foundation upon which a nation's economic aspirations rest. He added that efficient movement of people and goods is essential for productivity, competitiveness, and sustainable growth. He pointed out that Nigeria's infrastructure stock currently constitutes only 30% of the gross domestic product (GDP), this is well below the 70% benchmark recommended for middle-income economies. He noted that the low infrastructure stock value typifies a significant gap that reflects decades of underinvestment, maintenance neglect, and planning challenges. Furthermore, Mudasiru (2025) remarked that approximately 40% of Nigeria's road network remains in poor condition, while noting that rural areas are particularly affected, with many communities still relying on unpaved roads that are usually impassable during rainy seasons. Road infrastructure can therefore be considered as one of the most expensive assets for countries to develop and maintain; there is however usually not enough attention paid to its management and optimization of the expenditures related to it. The reason for this stems from numerous factors including the higher attention being given to the development of the road networks (as opposed to rational management and maintenance) and to the overall complexity of the technical and economic evaluation (Bonin *et al.*, 2017). Transportation agencies are usually faced with paucity of funds to adequately repair and rehabilitate every road section that deteriorate (Garber and Hoel, 2015).

Okechukwu (2020) in his address to Nigeria's House of Representatives while seeking support for the Bill for an Act to establish the Federal Roads Authority (FRA) said the problem of road infrastructure is not limited to any region in Nigeria; there is therefore a common consensus that Nigeria's road infrastructure is generally in a deplorable condition. National expenditure on roads which ought to be about 3.0% of GDP per annum has just been 0.05% - 0.1%. This is because funding the road sector has been strictly through fiscal allocation. Capital allocation to roads hovers always around ₦ 200 billion. Whereas the Federal Government had already awarded road contracts up to ₦ 4 trillion, liabilities on already completed portion stand at ₦ 306 billion. The nation unfortunately is being confronted with the stark reality of dwindling resources for appropriation and diminishing expenditure in terms of budgetary releases. In the 2019 budget for instance, ₦ 220 billion was allocated to Works, while less than ₦ 70 billion was released.

Road assets in Nigeria are faced with myriads of problems. Adetola (2011) pointed out that the quality of any work is often a factor of quality of material, methodology used and competence of personnel or supervisor. Morrow (2011) pointed out that almost without exception, most roads in Africa are poorly managed and badly maintained and noted that government roads departments are under resourced especially in terms experienced staff. The Federal government of Nigeria at various times recognized the problems associated with management of road maintenance. The Wey Commission of 1971, examined the organizational structure of highway development and management in five selected countries and recommended the formation of a Federal Highway Authority for the administration of all federal roads in Nigeria. Others include a Federal Government panel that recommended the setting-up of a parastatal (The Federal Highway Authority), the 'Road vision' 2000 arising from a workshop in 1996 and the setting up of the Infrastructure Concession Regulatory Commission (ICRC) in 2005. The proliferation of agencies seems to have created problems of overlapping objectives, responsibility and conflicts in the provision and management of road transport infrastructure and services (Adetola,2011).

Oyedele (2019), highlighted infrastructure challenges thus: wrong initiation and delivery of infrastructures, lack of effective monitoring and evaluation of projects, lack of finance, poor quality of infrastructure, lack of technical know-how, lack of ownership, lack of legal framework, technology, corruption, lack of maintenance economy, bad political environment, amongst others.

Mr. Vice Chancellor sir, some research findings noted here could address the myriads of problems of road infrastructure in the country.

5.1 Structural Evaluation of Flexible Pavement

The precarious state of roads in Nigeria is no longer in contention. The annual loss due to bad roads is valued at N80 billion while additional vehicle operating cost is put at N53.8 billion bringing the total annual cost to N133.8 billion. (Anyanwu, Adebusuyi, and Kukah, 2003). Consequently, one of the essential activities that is required to ensure that the tremendous amount of investment of hard-earned resources in road infrastructure does not go to waste is none other than effective and timely maintenance of these infrastructures. Postponed and delayed maintenance entails not only expensive reconstruction and rehabilitation, but also adversely affects and retards national development in all sectors of the economy (UNECA, 1982).

It is in light of the above that, a study aimed to address the issue of deteriorating road conditions in Nigeria was carried out. A model that utilizes easily accessible soil parameters to assess pavement stability was developed. The methodology involved collecting field deflection measurements using a Benkelman beam, obtaining field densities with a nuclear gauge, and collecting soil samples for various laboratory tests such as sieve analysis, Atterberg limits, and CBR tests. These tests were performed at every kilometre on a selected 36 km stretch along the Irrua to Auchi road. Subsequently, deflections, relative densities, soil activities, and CBR values were determined. Statistical analysis, specifically multiple linear regressions, were then used to establish the relationship between deflection as the dependent variable and relative densities, soil activities, and CBR as independent variables. The research used purposive sampling for data collection, with tests conducted at regular intervals along the road. Based on the regression analysis, a straight-line model expressed as in equation 1 was developed.

$$deflex. = 1.971 - 1.645RD \qquad \text{(Equation 1)}$$

where: *deflex. = deflection; and RD = relative density*

The study found a significant relationship between deflection and relative density. The model's accuracy was assessed by comparing the computed theoretical deflection values with actual field measurements. The model was validated via a T-test in which a validation check was carried out by comparing the deflection data from the study route; Irrua – Auchi road with deflection readings taken from another road; the Eket – Oron road. Model reliability and replication tests were also conducted. The results indicated no significant difference between the field measurements and the model's predictions, thus indicating a high level of accuracy. Statistical analysis showed that the relationship between deflection and relative density was significant ($p<0.05$), while the relationships between deflection and soil activities and deflection and CBR were not significant ($p>0.05$). The study's findings suggest that the model can be used to make decisions on when and how to repair or replace pavement, with good outcomes and economic savings. Policy and managerial implications are also touched upon, as the equipment for determining pavement deflection are not generally available in Nigeria. The research concludes that the developed deflection model is accurate and can be used for road evaluation, improving road asset management, and providing better scheduling for road maintenance and rehabilitation. It stresses the applicability of the model given the current challenges in road infrastructure evaluation within Nigeria. Recommendations include the need for adopting this model. The model provides a simple yet powerful tool for determining when and how to repair or replace pavement, thereby saving substantial costs (**Mohammed** and Dahunsi, 2012).

The model was used for the evaluation of the following roads - the religious centre road at Obafemi Awolowo University, Ile-Ife, the Obafemi Awolowo University - Obafemi University Teaching Hospitals Complex link road, and a section of Edunabon – Sekona Road.

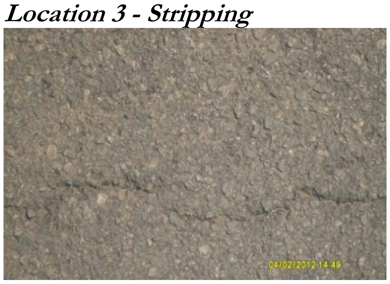
For the religious centre road, the relative rebound deflection was 1.32 mm was classified as poor. The selected visual conditions are as shown on Plate 2 (**Mohammed** and Afure, 2013).

Location 1 – Pot hole

Location 2 – Crocodile cracks

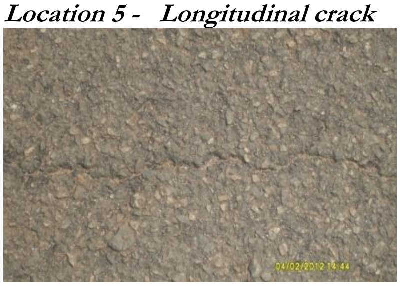
Location 3 - Stripping

Location 4 – Longitudinal crack

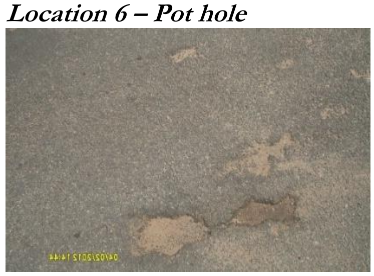


Location 5 - Longitudinal crack

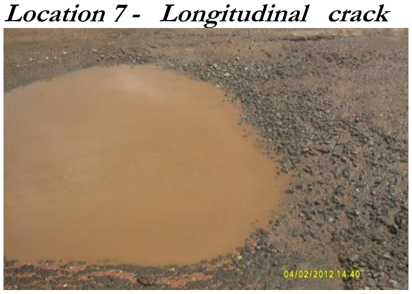
Location 6 – Pot hole



Location 7 - Longitudinal crack



Location 8 – Delineation



Location 9 - Pothole

Location 10 –Longitudinal and Transverse Cracks

Plate 2: Religious Road Defects

For the Obafemi Awolowo University – Obafemi Awolowo University Teaching Hospitals Complex link road, it compared pavement performance evaluations using deflection model and site reconnaissance methods (pavement rating score). A pavement rating score (PRS) of 61% was obtained from the condition survey, which suggests that the pavement is in good condition and thus required overlay only. A representative deflection value of 0.4 mm obtained also suggested that the pavement wasS in good condition. These results show that the two methods corroborate each other and could be used together to evaluate road sections for the optimum road maintenance option (**Mohammed, H.**, Elufowoju, E. F., Mgboh, V. C. and Ajibade, M. K., 2018)

The model was used to also evaluate a section of the Edunabon – Sekona Road in Osun State, Nigeria. A representative rebound deflection value of 1.10 mm, was obtained, which classified the section of the road as failed. Virtual pictures of some sections of the route are as shown on Plate 3 (Mohammed, 2022).

(a) Edge and Shoulder Damage

(b) Pothole

(c) Alligator Cracks

Pavement Failures at CH. 0+000 – 0+500

Rutting between CH. 3+000 and CH. 3+500

Delineation at CH. 4+500 at CH. 4+500

Culvert Inlet Overgrown

5.2 Pavement Evaluation Survey

Design standards for new road construction are based on the expectation that necessary maintenance will be carried out periodically to deal with the inevitable deterioration caused by traffic loading, climate effects and other deleterious influences. Consequently, road maintenance is a fundamental necessity, as important as the original road provision. The maintenance of the roadway asset must, additionally, be planned, designed and carried out in the knowledge that the road is there to provide a high level of service to users who, rightly, expect their needs to be met even when activities are being carried out on the network. Road maintenance is an essential activity for a number of reasons. First, various 'Acts' of 'The National Assembly' place legal obligations on road authorities to maintain their roads in a safe condition, and to ensure that maintenance operations are carried out safely. Second, roads are very often the 'vehicle' for carrying the apparatus of 'Statutory Undertakers', e.g. electricity, gas, water, and telephone lines, therefore, the work on provision and maintenance of supporting equipment are also controlled by statue. Third, well-maintained roads support national and local economies by ensuring that freight and businesses can move efficiently and safely. Fourth, the way of life depends substantially on the availability of the road network, e.g. the vast majority of trips to schools, shops, and hospitals, place of work and leisure activities are made via road network (Oliver, 2002).

Road maintenance results in faster and more comfortable travel time, opening-up of the farmland, easier access to harvested food and cash crops to urban locations, reduce the rate of deterioration of the road and thus prolong its life, lower the cost of operating vehicles on the road by providing good running surfaces, and enables greater regularity, punctuality and safety of road transport services. In order to examine methods of highway maintenance, the causes of structural failure must be defined and analysed so that remedial measures will successfully counteract or correct these failures (Oladele et.al, 2011). In spite of the importance of road maintenance, most roads in Africa are poorly managed and badly maintained. Almost without exception they are managed by Government-owned roads maintenance agencies that are under resourced especially in terms of experienced staff (Morrow, 2011).

The evaluation technique used by Government agencies and parastatals involved in road transportation in Nigeria is most often than not the visual means (i.e. condition survey). The visual means of pavement condition survey to say the least is subjective. Consequently, thorough and objective evaluations are not carried out, which result in proffering unsatisfactory maintenance strategies (**Mohammed** and Dahunsi, 2011).

The first step in the process of pavement management is to secure data about the condition of each pavement section in the system. Originally, condition data were obtained by visual inspections that established the type, extent, and severity of pavement condition. These inspections were subjective and relied heavily on judgment and experience for determining pavement conditions and programme priorities. Although such an approach can be appropriate under certain circumstances, possibilities exist for variations among inspectors, and experience is not easily transferable. In more recent years, visual ratings have been supplemented with standardized testing equipment to measure pavement roughness, pavement distress, pavement structural condition, and skid resistance (Garber and Hoel, 2010).

Investigations have revealed that many rehabilitated and/or reconstructed roads fail shortly after they have been put into use. A survey was carried to determine the adequacy or otherwise of some government agencies' road maintenance procedures. A structured questionnaire was distributed to thirty-eight respondents, including engineers and technical officers from Obafemi Awolowo University, Ile-Ife, Obafemi Awolowo University Teaching Hospitals Complex, and the works department of some selected local government areas within Osun State. The questionnaire gathered information on establishment, qualifications, experience in road maintenance, pavement evaluation techniques, and quality control/assurance tests. Thirty-two questionnaires were retrieved and analysed using SPSS. The findings revealed that a significant portion of respondents have limited experience in road maintenance. The survey revealed that 34.4% of respondents had less than five years of experience, 25.0% had 6 -10 years, and 40.6% had over 10 years of experience. The dominant pavement evaluation method was visual inspection (90.3%), with only a small percentage using a combination of visual, field, and laboratory tests (9.7%). The visual method being subjective in nature, as highlighted by previous research, raises concern. Furthermore, the results highlighted that only 29% of the agencies implemented quality control during construction/rehabilitation, and a mere 3% conducted quality assurance tests. The data points toward a deficiency in the implementation of quality assurance and control measures. The study concluded that the road maintenance practices of the agencies surveyed were inadequate. The research highlights that a substantial proportion of the respondents have less experience which could mean less precision during evaluation. The study also stresses that the dependence on subjective visual evaluation methods, the limited implementation of quality control, and the infrequent execution of quality assurance tests, collectively indicate that roads within these agencies' jurisdictions are poorly maintained and managed. This suggests the need for improvements in both the methods used for evaluating road conditions and the overall road management strategies (**Mohammed** and Bisiriyu, 2018).

5.3 Road Transport Accessibility Evaluation

Accessibility is an important factor in a road transport system, as it is a measure of the adequacy or otherwise of the system. A well developed and distributed road network will offer high levels of accessibility while less developed and distributed roads will have lower levels of accessibility. Rodrigue (2004), defined accessibility as the measure of the capacity of a location to be reached by or to reach different locations; therefore, the capacity and the structure of transport infrastructure are the key elements in the determination of accessibility. He remarked that, accessibility relies on two core concepts: (i) location – where the relativity of places is estimated in relation to transport infrastructure, since they offer the means to support movements, and (ii) distance – which is derived from the connectivity between locations. He added that, accessibility expresses the friction of space (or deterrence) and the location: the location which has the least friction relatively to others, is likely to be the most accessible. Nelson (2000) pointed out, that, accessibility can be calculated on a friction surface. A friction surface he noted consists of a regular two-dimensional grid where each cell in the grid represents either a transport route such as roads, railway lines, track or navigable rivers, or relatively inaccessible land and water bodies. He added that, different types of transport infrastructure have different characteristics – for example, a surfaced road will allow faster travel speed than a dirt road. He thereafter opined that, it is not enough in practice to measure the distance of a road connecting two locations/points; instead, a measure of travel cost (monetary or time) is preferable.

Sources, i.e. points of interest such as villages, hospitals, or schools are usually located in the transport network and can be therefore represented in another grid as cells that have a certain characteristic. All that is needed to create an accessibility map and two optional outputs are – point of interest and a grid where each cell value represents the cost of traversing that particular cell (Nelson, 2000). According to Pirie (1979), the following are methods for quantifying accessibility: distance measures, topological measures, gravity measures and cumulative-opportunity measures. These traditional methods, consider essentially, the road networks as against the whole territory as a continuous surface.

Mohammed and Dahunsi (2012), evaluated the road transport accessibility to Local Government headquarters in Edo state in Nigeria, using the geographical information system (GIS). The administrative map of the Edo State which shows the road network was acquired from the state Ministry of Lands and Housing was used to prepare the geographical information. Travel time measured in minutes was adopted as the cost unit and road category as main classifier. With the travel speed of each category of the road known, a weight map was created. The Local Government headquarters were taken as origins of travel and their accessibilities were evaluated through the cost surface modelling. Plates 4, 5 and 6, show the spatial distribution of roads, roads classification and accessibility time values to Local Government headquarters. From the accessibility map, the highest time cost of accessibility, was two hundred and four minutes, and forty-eight seconds. The study noted that, the method is suitable for regional assessment and planning of roads infrastructure as it reveals at a glance the level of road infrastructural development in the territory and its spatial distribution.

Plate 4: Spatial Distribution of Roads

Plate 5: Road classification

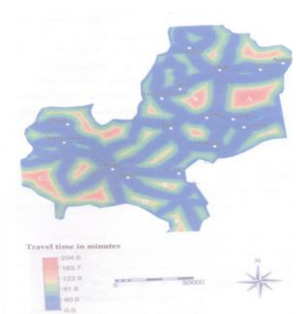


Plate 6: Accessibility Map

5.4 Road Subgrade

The pavement (flexible or rigid), rest on the subgrade, usually referred to as the formation level. It is the natural soil on which pavements rests, and it is its foundation. Subgrade soils occur as either residual soils formed by in-situ weathering of rocks or as transported soils formed by transportation cum deposition of fragments of pre-existing rocks (Gidigasu, 1976). It is therefore the ultimate determinant factor of road failure. Therefore, albeit the type of pavement, a poorly made subgrade, will result in pavement failure. Consequently, emphasis should be more on the quality of the subgrade. The following research findings could espouse this.

Mohammed and Dahunsi (2012), examined the effects of natural moisture content (NMC) on key engineering properties of soils and its link to road failures. The study found out that when the natural moisture content (amount of water) of earth fill materials for subgrade is higher than its optimum moisture content (usually determined in the laboratory) adequate compaction cannot be attained. The study recommended that, NMC tests be conducted before earthwork operations to ensure the appropriate density indices and, therefore, minimize the chances of pavement failure.

Furthermore, **Mohammed (2017, 2022)**, opined that, relative compaction values of road foundation soils, at every level of compaction, must be at least 95% relative compaction values at all times to avoid excessive pavement deflection and subsequent failure.

Evaluation of highway pavement performance should consider factors such as geology and geomorphology of the terrain traversed by the roads. The texture, structure and mineralogical composition of the parent rocks have pronounced effects on the geotechnical properties of their derived soils (Gidigasu, 1976; Meshida, 1981; Meshida, 1987 and Ajayi 1987).

Mohammed and Salami (2013), investigated the Irrua-Auchi road, a section of the Warri-Benin-Abuja highway in Nigeria, to understand how subgrade soil properties influence pavement performance and road failures. The study showed that pavement deflections reflected the influence of soil structures derived from the stratification of the underlying geologic units implying that the geological and geomorphological factors have a strong impact on pavement performance. Furthermore, it revealed that hydrology is an important factor to highway performance, especially in the least stable segment of the road, which traverses floodplains of several perennial rivers; this highlights the significance of geology in pavement design and evaluation. The study concluded that geotechnical field tests, reflecting the intrinsic geological properties of subgrade soils, can be a more reliable measure for pavement evaluation in sedimentary rock terrains than laboratory tests.

5.5 Asphaltic Concrete Mix Modification

Asphaltic concrete is derived from a mixture of coarse and fine aggregates, stone dust, mineral fillers and binder (usually bitumen). The asphaltic concrete mix is produced such that the finished product does not have too much bitumen which can eventually lead to bleeding and frictionless surface, or too much coarse aggregate which lead to ravelling of the surface. The bitumen and aggregates are usually mixed and heated at a central location. Asphaltic concrete surfaces are fairly easy to construct and repair (Ramakrishna and Sundararajan, 2005a). Longevity of asphalt road is in high demand as part of reducing expenses for public infrastructure and maintenance costs. Conventional asphalt concrete pavement has several draw backs. It is susceptible to rutting caused by traffic load and damage caused by petroleum oils (Hirato et al., 2014). Mat et al. (2014) opined that, flexible pavement deterioration can be minimized and increase in its service life ensured, if the bituminous layers are improved with regards to performance properties, such as resistance to permanent deformation, fatigue, wear, stripping, aging amongst others. The properties of the binder in asphaltic concrete pavement govern its performance as studies have shown that pavement distresses are related to the rheological properties of the binder (Taher and Aman, 2017). Modifiers can improve the properties of asphaltic concrete mixtures; such as stiffness, which at normal service temperatures will increase rut resistance and at low temperatures improve its resistance to thermal cracking (Roberts et al., 1996). Application of modifiers to asphalt mix results in its improved properties compared to conventional mixture (Gawel et al., 2011).

In the light of the above several studies were carried on modification of asphaltic concrete mix. **Mohammed,** and Umoru (2014), explored the use of crushed palm kernel shell as a partial replacement for fine aggregate (sand) in asphaltic concrete with a view to assessing the impact of this replacement on the properties of the asphalt mix, potentially utilizing a waste product for sustainable construction practices. The result showed that, 10 and 50% partial replacement of fine aggregate (sand) with crushed palm kernel shell produced properties of asphaltic concrete within the specifications for asphaltic concrete roads.

Adebayo and **Mohammed** (2016), investigated the effect of pulverized coconut fibre (PCF) as an additive in asphaltic concrete. The result showed that at optimum bitumen of 5% and PCF content at 8%, the Marshall Stability increased indicating improved strength. The study concluded that PCF as an additive in asphaltic concrete could absorb high road temperature, over loading, rutting and moisture resistance of flexible pavements. Likewise, Osuya and **Mohammed** (2017), evaluated the effects of sawdust ash (SDA) on the characteristics of asphaltic concrete. The findings showed that the inclusion of SDA improved asphaltic concrete properties. The optimum SDA content was found to be 15%, achieving stability, flow, density, VFB, AV, and VMA values of 18.2 kN, 3.40 mm, 2.36 g/cm^3, 77.13%, 4.05%, and 17.71%, respectively. The study concluded that SDA has the potential to enhance asphaltic concrete properties, thereby making it a valuable alternative for mineral filler in the pavement industry, and addressing waste management by utilizing sawdust byproducts. Furthermore, Aderemi, **Mohammed** and Olonade (2018) investigated the effects of cassava peel ash (CPA) as partial replacement for granite dust in asphaltic concrete. The study concluded that, 2 % CPA replacement of granite dust could be accepted as an optimum replacement to improve the performance of asphaltic concrete. Also, **Mohammed**, Adebunmi and Adewole (2020) investigated the effect of coal bottom ash (CBA) on the characteristics of asphaltic concrete. The results revealed that CBA improved the asphaltic concrete's characteristics. Compared to the control mix (0% CBA), the 20% CBA mix displayed improved stability (16.97 kN), density (2.514 g/cm^3), and VFB (71.2%), alongside reduced air voids (3.4%) and VMA (11.9%). The study showed that, coal bottom ash can be used as a partial replacement of fine aggregate in asphalt concrete to improve its Marshall parameters. The research suggests a cost-effective way to reduce reliance on natural resources in highway construction, as the rising cost of resources prompted research to look into replacing conventional materials, such as coal ash.

In research conducted by Ezemenike and **Mohammed (2017)**, the effect of polyethylene terephthalate (PET) as an additive in asphaltic concrete was studied. The Marshall Stability tests revealed an increase in stability up to an optimum PET content of 8%, along with decreased flow. Furthermore, the air voids and voids in mineral aggregates decreased, while the void filled with bitumen increased with the addition of PET. These improvements are attributed to enhanced adhesion between the PET-modified asphalt binder and the aggregate particles. The study concluded that PET has the potential to improve asphaltic concrete properties, leading to increased fatigue resistance, better thermal stress cracking resistance, and reduced rutting. The findings align with previous studies highlighting the benefits of using waste plastics in road construction, and also suggest that it reduces the cost of road construction. Also, Akasi and **Mohammed** (2018) evaluated the effect crumb rubber (CR) as partial replacement of coarse aggregate in asphaltic concrete. The research findings revealed the Marshall stability decreased with increasing CR content, attributed to the CR's lower hardness, the flow increased with CR content due to the rubber's elasticity, while bulk specific gravity decreased with higher CR percentages due to CR low density decreased as CR increased due to increased air voids. VMA increased with CR content, indicating that CR could not effectively fill the voids and concluded that the partial replacement of coarse aggregate with crumb rubber improved the properties of the asphaltic concrete. In the same vein, **Mohammed** and Adefesobi (2020) evaluated the potential of Sasobit polymer as an additive in bitumen and asphaltic concrete. The study found that adding Sasobit polymer enhanced the stability of the asphaltic concrete. It also, decreased the flow value of the mix, indicating a reduction in binder viscosity, which in turn, influences mixing and compaction temperatures, workability, and rutting potential, alongside improved pavement elasticity. The study concluded that Sasobit, as an additive, improves the properties of asphaltic concrete and this enhancement can reduce energy consumption by decreasing the mixing and compaction temperatures. The study thus highlighted Sasobit's potential to reduce greenhouse gas emissions and improve pavement durability. A Sasobit® at mix – ratio of 1.7% bitumen – polymer mixture was therefore recommended.

5.6 Transportation Planning and Management

Transport planning, operation and evaluation are crucial for a sustainable road network system. Transport planning is a systematic technique of understanding traffic and transportation characteristics, associated problems and requirements, with a view to creating safe, efficient and expedient transportation system that will meet current and future needs, and preferences of an individual and the community and promote social and economic development (Saxena, 2014). Periodic operational performance evaluation of the road system could address traffic growth and proffer solutions to deficit in its infrastructure (Ajibade and **Mohammed**, 2016).

Mohammed (2014), carried out an operational evaluation of Road 2 – Road 6 intersection at Obafemi Awolowo University, Ile- Ife, Osun State, Nigeria, the finding showed that the average intersection delay was, 13sec./veh., which put the level of service (LOS), at B. The study concluded that, there is a slight delay at the intersection, which could probably be attributed to the inadequate geometrics of the intersection. A new geometric configuration was therefore proposed to eliminate this delay. Plate 7 shows the intersection location, while Figures 1 and 2, show the existing intersection configuration and the proposed new configuration respectively.

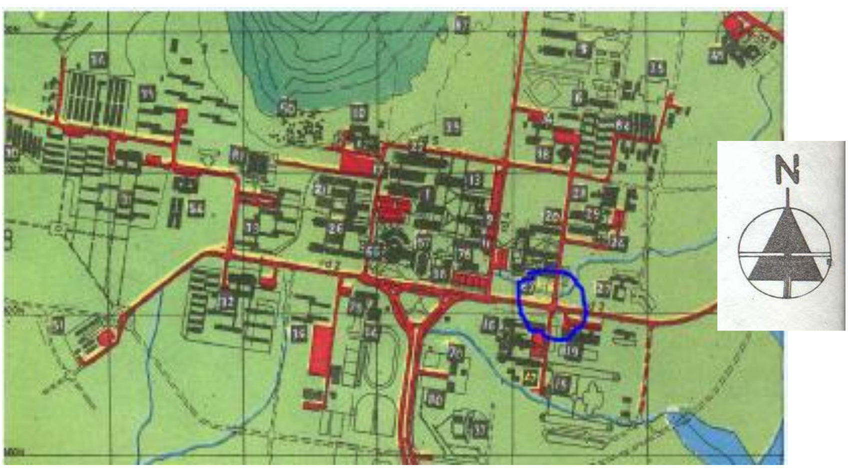


Plate 7: Intersection Location

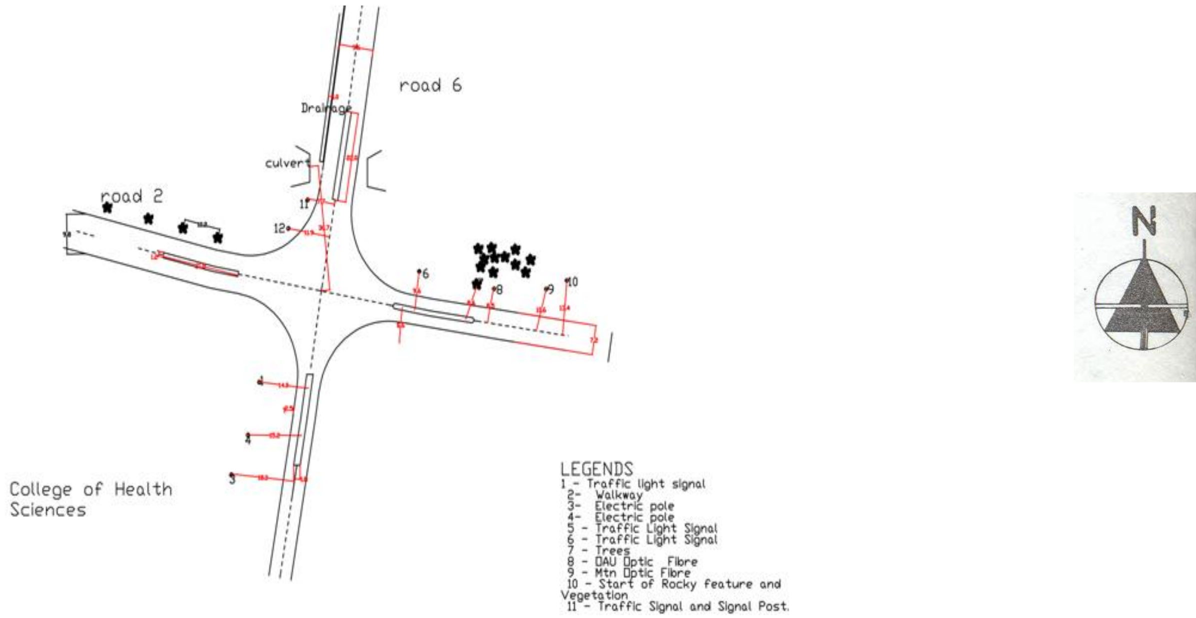


Figure 1: Existing Intersection Configuration

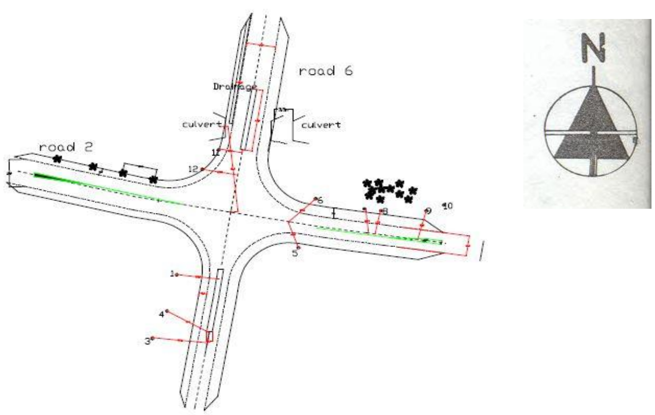


Figure 2: Proposed New Configuration of Intersection

Cities and traffic have developed hand-in-hand since the earliest large settlements. The same forces that draw inhabitants to congregate in large urban areas also lead to sometimes intolerable levels of traffic congestion on urban streets and thoroughfares. Road traffic congestion poses a challenge to all large and growing urban areas (ECMT, 2007). Aderamo (2012) noted that, urban transport problems remain one of the most nagging problems in urban transportations today. All over the world, attempts have been made to tackle the problems, yet the situation seems to get worse. Cities are centres of economic, social, cultural and intellectual activities. These activities result in the drift of the population from rural to urban centres and these congregations have caused cities to expand without control in many areas, causing congestion, environmental and social problems. In developing countries, rapid urban growth is overstepping the capacity of most cities to provide adequate services for their citizens (Cohen, 2004). Furthermore, lack of infrastructure and weak maintenance put extra stress on growing traffic flows, resulting in congestion, pollution and a low road safety level (Rust et al., 2008, Cohen, 2004, Gakenheimet, 1999 and Gwillian, 2003). Urban mobility problems in Nigeria had been on the increase since independence. This is due to rapid increase in population in urban areas, which is not matched with growth in transport facilities such as road network, transport complimentary facilities, transport services and traffic management techniques (Ogunbodede, 2008). Improved mobility in urban areas in developing countries is possible by building new infrastructure. However, this is a long-term solution and expensive. A short-term solution is to improve the traffic management to rationalize the use of existing infrastructure (Gakenheimer, 1999). Rothenberg (1985) defined urban congestion as "a condition in which the number of vehicles attempting to use a roadway at any given time exceeds the ability of the roadway to carry the load at generally acceptable level of service". There are two types of congestion: recurring and non-recurring. Typically, recurring congestion occurs during the morning and afternoon rush hours as commuters travel to and from work. Non-recurring congestion is caused by random incidents, most often by disabled vehicles and accidents. Recurring congestion is most easily identified as the characteristics of rush hour traffic are well documented. Incidents are random events, and traffic patterns and characteristics are not well defined (Arnold, 1985). Traffic congestion is a hardy and annoying urban perennial problem. If Glaeser and Kahn (2004) had argued that cities are the absence of space between people, then traffic is the inevitable friction that keeps them apart. Understanding, measuring and dealing with transportation problems are key challenges for city and national leaders (Corpright, 2010). Measuring congestion is a necessary step in order to deliver better congestion outcomes. Good indicators can be based on a wide network of roadway sensors but simple indicators based on less elaborate monitoring can sometimes adequately guide policy. According to ECMT (2007), what is important is to select metrics that are relevant to both road managers (e.g. speed, and flow, queue length and duration, etc.) and road users (e.g. predictability of travel times, sustain reliability etc.). Transportation performance measures; based on travel time quantities satisfy a range of mobility purposes. They show the effect of many transportation and land use solutions and they are relatively easy to communicate to a range of audiences. A variety of different measures can be created to show the effect of mobility problems and solutions on individuals, regions, businesses and the economy. There are also several ways to calculate or estimate the travel time measures including roadway inventory and traffic files; travel speed datasets from system monitoring devices or companies, computerized transportation demand models and simulations of traffic flow. Each of the measures and data sources has their strengths and weaknesses, and each is better suited for some applications (Lomax and Schrank, 2010). The basis of travel time measure is rooted in the interests of travellers and urban residents. Travel time indices are good measures of the effects of congestion; they rely on an estimate of the speed that travellers choose to travel if there is no congestion (in this case, 90 km/h (60 mph) for freeways and 45 km/h (30 mph) on streets (Lomax and Schrank, 2010). Operational performance evaluation indices for road networks could therefore, give policy guide to improve existing road infrastructure and ensuring better traffic management.

Ajibade and **Mohammed (2016)**, investigated the operational performance evaluation of Post Office –Teaching Hospital Road, Ile-Ife, Nigeria. Speed and traffic flow data were collected for morning and evening peaks for seven days for two segments of the selected urban road in Ile-Ife, using normal procedure. Traffic flow parameters, such as, travel speed, traffic volume and capacity were computed and operational performance evaluation determined. The study showed that, motorcycles were the predominant means of transport (50%), and followed by buses (25%), cars (23%) and trucks (2%), while the average travel speed was 41km/h, which aptly, described the subsisting traffic mix of the route. The average traffic capacity of 1306 passenger car per hour per lane (pc/hr./ln) was also obtained. The results revealed that the operating capacity and speed of the road were short of the required values of 1500 pc/hr./ln and 50 - 60 km/h respectively, for an urban two-way, two-lane highway. The study concluded that, the road is therefore prone to congestion.

Headway, a measure of level of service of a roadway, is another instructive method in addressing traffic congestion. Emmanuel and **Mohammed** (2020), investigated traffic congestion using time headway as an index in Ile-Ife, Nigeria, in other to understand urban mobility problems exacerbated by inadequate infrastructure and rapid population growth. Headway, traffic flow and travel speed were collected for morning and evening peak periods for three consecutive weeks for two selected sections of a road in Ile-Ife (Sabo junction – Obafemi Awolowo University Teaching Hospitals Complex), Osun state, using normal procedure. The obtained headway data were subjected to statistical analysis. Headway models were developed using regression analysis and the developed models were evaluated using Adjusted coefficient of determination (Adjusted R^2). The results showed that the traffic along the road was heterogeneous. The maximum safe speed (85th percentile speed) was 31.20 km/hr., while the minimum allowable speed (15th percentile speed) was 28.50 km/hr. The ratio of flow to capacity (v/c) of the road was 0.65 and thus characterised to operate at level of service C. The headway models are as shown in equations 2 and 3:

$h = 0.001n^2 - 0.418n^2 + 35.401$ Equation 2

$h = 0.002n^2 - 0.569n + 42.122$ Equation 3

where: 32

h = headway (secs)

n = headway observations

The coefficient of determination (R^2) values for equations 2 and 3 are 0.942 and 0.928 respectively. The minimum headway for section one of the road is 5.35 sec, while section two recorded a minimum headway of 5.52 sec. The study concluded from the results obtained that the road is prone to congestion.

An intersection is a convergent area where two or more roads meet with a provision for changing route or directions. There are different types of intersections depending on the number of roads converging at a point and the structures made available for the flow of traffic at such convergent areas. Basically, intersections can be classified into three categories: At grade, grade-separated without ramps and grade-separated with ramps intersections (Garber and Hoel, 2015). The American Association of State Highway Officials [AASHTO] (2001), recommends not more than four legs at an intersection. This is because the number of possible conflict points at any intersection depends on the number of approaches, the turning movements, and the type of traffic control present at the intersection. AASHTO (2001) pointed out that, an un-channelized cross intersection is used mainly at locations where minor or local roads cross, although it also can be used where a minor road crosses a major highway – however, in these cases, the turning volumes are usually low and the roads intersect at an angle that is not greater than 30 degrees from the normal. Furthermore, AASHTO (2001) remarked that, right turning roadways are provided for four leg intersections when right turning movements are frequent and also in suburban areas where pedestrians are present. Congestion may also result from delay caused by convergence of traffic movements at an intersection, thus creating conflict points. These conflicts occur when traffic streams moving in different directions interfere with one another. The three possible types of conflicts are; merging, diverging, and crossing (Garber and Hoel, 2015). Conflicting vehicle movements at intersections are probably the largest cause of accidents in many developing countries (Thagesen, 1996). Thus intersection should be aimed at reducing the potential conflicts of movements of vehicles, pedestrians and facilities (Oguara, 2006). In order to control conflicting and merging traffic streams to minimize delay, intersections are usually needed. Choice of geometric parameters that control and regulate the vehicle path through the intersection could ensure this (Roger, 2003). Saxena (2014) pointed out that, intersections are critical spots along a road. Capacity is the maximum sustainable flow rate at which vehicles or persons reasonably can be expected to traverse a point or uniform segment of a lane or roadway during a specified time period under given roadway, geometric, traffic, environmental, and control conditions; usually expressed as vehicles per hour, passenger per hour, or persons per hour (National Academy of Sciences, 2000).

Road intersections manage traffic flow, and their quality impacts overall traffic flow, safety, and capacity. It highlights that channelized intersections guide traffic, while traffic signals effectively control crossroads. Factors like traffic awareness, economic considerations, and the number of lanes is crucial for design, considering vehicles speed and pedestrian movement. Assessment of intersections reveal congestion, using delay as a key indicator of efficiency for signaled and unsignalised intersections, especially during peak hours.

Mohammed, Oyebode and Oyefeso (2020), carried out the operational evaluation of Obafemi Awolowo University Main Gate – Ede Road Intersection to assess its operational efficiency. Geometric survey of the intersection was carried out. Peak hour traffic studies were conducted for a week and the traffic characteristics and volume were determined using standard procedure. The level of service (LOS) of the intersection was thereafter obtained. The geometrics of the intersection showed that, two lanes exist on the East Bound (EB) and West Bound (WB) approaches, as well as a dual lane on the North Bound (NB) and South Bound (SB) approaches. The traffic volume count were, 1378, 931, 1168 and 1123 veh./hr. for the NB, SB, EB and WB lanes respectively. The level of service at the intersection was B, thus implying that it exhibits a slight delay.

Mohammed, Ajayi, Olawuyi, and Oriaje (2020), assessed the operational efficiency of the Oja-Oba intersection in Osogbo, Nigeria, due to observed traffic congestion, especially during peak hours to determine its level of congestion. A visual inventory and condition survey were conducted. A digital video camera, strategically mounted, captured traffic during morning and evening peak hours for a week. The study used standard procedures to assess the Level of Service (LOS). Calculations were performed on peak hourly flow (PHF), hourly flow rate, proportion of heavy vehicles and their adjustments, critical gap and follow up time, potential capacity of the minor movement, capacity of shared lanes, and control delay. The result study showed that the average delay at the intersection was 24 sec/veh., and therefore classified as operating at class C level of service; implying that flow is stable, but speeds and maneuverability, will be more closely controlled by the higher volumes. Consequently, most drivers using the intersection will be restricted in their freedom to select their speed, change lanes, or pass.

Mass transit is characterized by fixed routes, published schedules, designated networks, and specified stops. The availability of a wide variety of mass transit services is a major element of developing a sustainable transport system. The competitive advantage mass transit has over private transport include, energy conservation, road space use, user cost and reduction in carbon emission production. The travel needs of urban passengers to a large extent can be effectively provided by mass transit services. However, the travel demand of the citizens varies based on their income, trip purpose and the distance they need to travel. Consequently, having one type of public transit service is not sufficient as it cannot serve the ever-expanding transport needs of everyone and for all purposes. In essence, a balanced transport system is important to satisfy various types of transport demand. In order to develop a balanced transport system, the provision of appropriate types, availability and frequency of services by different public transit modes is desirable (Hutton, 2013). Transportation planning is an ongoing process that seeks to address the transport needs of the residents of an area, and with the aid of a process of consultation with all stakeholders, strives to identify and implement an appropriate plan to meet these needs (Roger, 2003). It is a well-known fact that much urban movement, especially from home to work depend on public transport (Oglesby, 1975). The basic purpose of transportation planning and management is to match transportation supply with travel demand, which represents 'need'. A thorough understanding of existing travel pattern is necessary for identifying and analyzing existing traffic related problems. Detailed data on current travel pattern and traffic volumes are needed also for developing travel forecasting/prediction models. The prediction of future travel demand is an essential task of the long-range transportation planning process for determining strategies for accommodating future needs. These strategies may include land use policies, pricing programmes, and expansion of transportation supply – highways and transit service (Arun et al., 1975). Origin and destination (O-D) survey is a low-cost manual estimation of matrix of traffic (Slinn et al., 2011). O-D survey establishes an understanding of why people travel. The survey data will elicit where the trip begins and ends, the purpose of the trip, the time of the day, and the vehicle owner/or operator, amongst other information. The O-D survey can be carried out through home interview or at bus stops. O-D survey information could also be requested by telephone, by return post cards, by e-mail and by internet (Garber and Hoel, 2015). Transportation demand analysis seeks to describe travel in meaningful ways, to explain travel behaviour and on the precinct of understanding of travel behaviour, predict demand for various types of transportation services (Banks, 2004). Likewise, Mannering et al. (2012), opined that the number of vehicle-based (automobile, bus or subway) trips is a function of various socioeconomic and/or distributional (residential and commercial) characteristics: pointing out that, for this reason, trip generation models generally assume a linear form. They added that, the model is usually developed from data collected from commuters' survey.

Mohammed, Akodu and Alalade (2019), carried out a preliminary study of mass transit system for Obafemi Awolowo University - Obafemi Awolowo University Teaching Hospitals Complex, Ile-Ife, link road, with a view to developing a sustainable transport system for the route. The study identified land use activities like hospitals, schools, and residential buildings, alongside existing transport facilities like bus terminals and a car park, the number shuttle vehicles and commuters for the route. The study underscores the importance of a balanced transport system, considering travel demand variations based on income and purpose and posit that transportation planning should align supply with demand and should involve stakeholders' consultation to identify and implement appropriate plans. A trip generation model (equation 4) was developed to enable future trip forecasting and mass transit vehicle provision planning

$$T = 4.220 + 0.005\, z_1 + 0.148\, z_2 + 0.0892 z_3 \qquad \text{Equation (4)}$$

Where;

T = number of trips, Z_1 = income, Z_2 = household size, and
Z_3 = number of vehicles.

5.7 Terminals and Terminal Facilities

Enhancing the effectiveness of public transportation systems requires an understanding of the variables affecting dwell time at bus terminals. Milkovits (2008) and Puong (2000) established that headway, boarding time, and bus capacity are important factors that influence waiting time; using a variety of approaches to measure their effects. One crucial operational factor influencing dwell time is headway, or the amount of time that passes between successive buses on the same route. Increased passenger accumulation during stops is frequently linked to tight headways, which results in longer dwell durations. In the investigation of the connection between stay time and headway variability, Tirachini and Hensher (2021) noted that erratic headways worsen terminal crowding, which lengthens the boarding and alighting procedures. In a similar vein, Gao *et al.* (2020) modelled the impact of headway on dwell time using real-time data from metropolitan bus systems and showed that lowering headway variability considerably shortens average dwell times. Delgado *et al.* (2019) suggested adaptive control techniques for headway stabilization, emphasizing how well these techniques to cut down on excessive dwell periods brought on by an unequal passenger distribution. This implies that resolving headway anomalies might improve service dependability and expedite terminal operations.

Elufowoju, **Mohammed** and Ayodele (2025) investigated the relationship between bus dwell time and various terminal-based factors, crucial for public transportation efficiency and passenger satisfaction. The study, conducted at Terminal 3 of Oshodi Transport Interchange in Lagos State, Nigeria, analyzed headway (time between bus arrivals), dwell time (time at the terminal), boarding time, and the number of passengers. Data collected in the year 2024, with 481 records, showed a significant correlation between dwell time and boarding time and number of passengers, with Pearson correlation analysis. The research then employed regression analysis to further investigate how these variables influence dwell time. The results showed that boarding time and number of passengers positively correlate with dwell time, indicating that longer boarding times and higher passenger volumes extend the time buses spend at the terminal. Conversely, the study revealed a negative, correlation between headway and dwell time. The study concluded that, reducing boarding time and improving passenger management will enhance operational efficiency and passenger satisfaction. The study underscored the need for transit managers and planners to prioritize these aspects as strategies for terminal management.

5.8 Concrete vs. Asphalt Roads in Nigeria which is Better

Nigeria's Works Minister, David Umahi, favours rigid concrete pavement for roads over the prevalent flexible asphalt. This stems from the perceived poor condition of existing asphalt roads. Rigid pavement uses reinforced concrete, while flexible pavement relies on a bituminous (tar) overlay.

Mohammed (2023), gave some insights into the issues raised by the Minister’s decision thus: the choice is between additional service and higher cost or reduced service and lower cost. This is a design challenge. The decision is not only technical, but also political.

Rigid pavements are generally more expensive and difficult to construct and maintain. They are made out of a cement concrete with a base, sub base and subgrade underlay. Unlike flexible pavement, rigid pavements have a high flexural strength, making every layer virtually immune to bending under pressure. Flexural strength is the material's ability to resist deformation under load. Flexible pavement is designed to bend or deflect according to external factors like traffic loads. Essentially, it is more adaptable to the elements to which it is exposed. The initial cost of construction is low and with excellent regular maintenance, it has a lifespan of about 10-15 years. Regular maintenance is required for this type of pavement, and repair work is fairly easy. Flexible pavements have low initial cost, but higher maintenance cost. Comparatively, rigid pavements have high initial cost, but low maintenance cost.

Asphalt has a relatively smaller surface area of subgrade compared to a wider surface area for reinforced concrete. Subgrade is the material underneath the pavement structure. Flexible pavements usually last for 10 to 15 years while rigid pavements last for 25 to 30 years. There's a higher water penetration rate for flexible pavement but lower rate for rigid pavement. The longer moisture remains in a flexible (asphalt) pavement structure the more likely pavement failure will occur. In particular, the continuous presence of moisture in a pavement subgrade can significantly affect the subgrade's modulus and reduce pavement performance. Subgrade modulus is a conceptual relationship between applied pressure and deflection for a plate resting on an elastic support system. Night driving is better on rigid pavements due to the light-coloured surface. Extreme weather like high temperature affects flexible pavements but not rigid pavements. In flexible pavements, temperature fluctuations have a significant impact on structural performance, including stress and strain. Noise pollution is also high on flexible pavements but lower on rigid pavements.

The choice of any type of pavement depends on the life cycle and costs of materials, which include initial construction cost, maintenance and repair cost, and cost associated with environment factors such as emissions and energy consumption. Consequently, a life cycle cost analysis should be carried out before choosing a pavement type.

A well-designed road should provide the intended level of service at an acceptable level of safety. It will also reflect local values and policy, which will vary from location to location, and it will place appropriate importance on cost, environmental values and appearance. These should guide the country's decision on the issue.

6.0 Academic Exploits and Awards

Mr. Vice Chancellor sir, I joined the academic rank of the University, as a Lecturer I in 2010 and eleven years later, in 2021, I was pronounced a Professor of Civil Engineering.

I successfully supervised Nine (9) Masters students by research and two (2) PhD students (one co-supervised). I served as an examiner to Faculties of, Technology, Science and Environmental Design and Management. I also served as external examiner to Federal University of Technology, Akure, Ekiti State University, Ado-Ekiti, University of Ibadan, Ibadan and Federal University of Agriculture, Abeokuta. At international stage, I served as an examiner, for a Masters degree for University of Johannesburg, 2018 and a PhD degree for University of Rwanda, 2024.

I currently serve as an external examiner for the B.Eng. and B.Sc. degree, Civil Engineering, programmes for the Osun State University, Osogbo and the University of Ibadan, Ibadan, respectively.

I served as a professorial assessor for some universities in the country.

I received 2024 West Africa Science Communication Award, for the road engineering article, titled "Concrete versus asphalt for Nigeria's roads: which is better?", as the most-read article on The

Conversation Africa between November 1, 2023, and October 31, 2024. I was also appointed as a ConstructAfrica Ambassador as part of the 'African Leaders in Construction' ConstructAfrica Ambassador Programme.

7.0 Concluding Remarks

Mr. Vice Chancellor sir, my research findings have shown that, the state of roads in Nigeria is precarious making road transportation arduous and perilous. In addition, traffic demand is significantly on the increase on the roads without a commensurate increase in the rate of road infrastructural development. Besides, the operational and performance evaluation of the road infrastructures are not regularly and timely carried out, and finally, the cost of road construction is constantly on the high side, the use of alternative materials as espoused could address this.

8.0 Closing

Mr. Vice-Chancellor sir, this is it; 'That We May Not Overtake Death'.

I thank you all for listening.

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