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A CONSIDERATION OF PAVEMENT TYPE SERVICE LIFE CAPACITY FOR SUSTAINABLE INFRASTRUCTURE DEVELOPMENT IN NIGERIA

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ABSTRACT
The opposition over the use of concrete pavement against the conventional flexible pavement in Nigeria cannot be overemphasized; nevertheless, the question of interest should be: is concrete pavement now a way out of Nigeria road network? Certainly, the success of any road pavement design practice is a function of various factors put together. Yet, the pros and cons of concrete pavement should not be seen from the perspective of a political drive but rather seen on the feasibility of achieving a reliable and sustainable pavement during the intended service life. The necessary factors to be considered in the success of pavement design will depend on; the environmental condition, geotechnical properties of the concrete pavement materials, the mix design of the concrete, the construction practice/workmanship, the expected load cycles and social acceptability. Furthermore, the emphasis on concrete pavement should be as a result of positive success already in use and the viability of the use of concrete pavement over flexible pavement will rely on successes and failures in design and construction which will depend on laboratory testing data so as to generate a code of practice manual which is suitable for a particular geographic location; since soil properties and environmental condition lies in its abundant complexity over a given location. This paper focuses on providing a guide to the use of concrete pavement design in Nigeria and how success in transforming Nigerian roads to rigid pavement can be achieved especially in failed road sections within the southern region and other regions prone to excessive rainfall precipitation.

Keywords: Life Cycle Assessment, Service Life Capacity, Social Impact Assessment, Sustainable Pavement

1. INTRODUCTION
A few decades ago, the use of concrete as a pavement material in road applications has not gained importance in Nigerian Highway design. However, the use of flexible pavement over the years has achieved a decline in the durability and sustainability of Nigerian roadways due to several factors like; design formulations, environmental conditions, underestimated load cycles, and poor maintenance culture (Oke *et al*, 2013). NIStructE President, Engr Samuel Ilugbekhali stated "Considering the recent endorsement of the use of concrete pavement by Nigerian Institution of Structural Engineers (NIStructE) the time has come when Nigeria

should step up the use of concrete for roads especially now that the country has increased its potential to produce cement at lower prices and even exporting to other countries" (ISCP, 2015). This paper seeks to develop a guide and state-of-the-art methodology pertinent to concrete design construction and practices. Overall, pavement design entails the sound application of acceptable engineering criteria and standards, yet the standards which this study seeks, will provide is a basic uniform design practice for typical pavement design situations, however, precise rules which would apply to all possible situations are impossible to give. Furthermore, this paper introduces a premise to harnessing the nitty-gritty of what is expected to undertake a strategic developmental plan for road pavement type and proposes a research paradigm to solving the complications generated with choice and accuracy of pavement type relative to the local environment the project is set for. The initial start point for this would be the input variable for Service Life capacity (SLC) which are; design consideration, material quality, construction practice and maintenance culture. However, the proposed study is structured as follows: a literature review on pavement failure with regards to Design Considerations, material properties, construction practice, maintenance strategy, followed by the research methodology and the proposed framework for sustainable development.

According to Ioannides (1991), pavement is a complex engineering system, whose analysis and design involves the interaction of three important components; the natural supporting layers, the constructed layers, and the geometry of the applied loads. The importance of the first two components is self-evident; the third is dictated by the prevailing use of linear elasticity, which robs the level of the applied load of its natural significance.

Materials used in pavements depend largely on their availability, social considerations, economic considerations, environmental considerations, design specifications and previous experience (Bureau for Industrial Cooperation, 2012). On a general note, pavements can either be flexible, rigid or composite; although, composite pavements are very much durable than others, yet, composite are not commonly used as a result of economical reason. However, pavements are called flexible and rigid based on the stiffness of the surface layer relative to the subgrade layer. Further, the major difference between these pavements type is the manner in which vehicular loads are distributed to the subgrade. Rigid pavement distributes the vehicular load over a relatively large area; this is as a result of the high modulus of elasticity of the concrete slab and the major portion of the structural capacity is provided by the slab.

Consequently, the design of the concrete slab is a major factor to the structural strength of rigid pavement design and additionally, the supports from the subgrade is of importance; as minor variations in subgrade strength have little influence upon the structural capacity of the pavement. Unlike rigid pavement, flexible pavement load-bearing capacity is derived from the load-distributing characteristics of a layered system and may consist of a series of layers, or a single layer, with the strongest materials typically at or near the surface. The strength of such pavements lies in the buildup of layers to distribute the load over the subgrade. The design thickness of the pavement is influenced appreciably by the strength of the subgrade and up until recent years, these pavements are commonly used worldwide, and the case of Nigeria is not an exception.

Although, the use of flexible pavement has so many advantages such as; low tire-pavement noise generation, smooth surface and environmentally sustainable roads (Asphalt Pavement Alliance, 2010). Its preference is evident in the case of Nigeria and South Africa as about 90 percent of the paved roads are flexible pavement (De Beer *et al*, 1999). Yet, flexible pavement still experiences failure and thus, Nigeria roads are at a dilapidating state. The failure of flexible pavement has generally been associated with; low bearing capacity of soil used in different layers, overloading of the pavements, inadequacy in designs, lack of good drainage system, poor construction practices and maintenance culture, and severe environmental condition (Kordi *et al*, 2010; Shafabakhsh *et al*, 2013; Aderinola and Owolabi, 2014). Thus, a paradigm shift is rather of great importance in this situation.

Road failure rate in Nigeria is in an alarming state, as most roads constructed in the last 6 years have experienced failure within the first year of construction as a result of certain environmental factors, poor design construction methods and practice, poor material specification, excessive traffic generated on such newly constructed routes due to the ease of movement and smooth-riding (Osuolale *et al*, 2012; Aderinola and Owolabi, 2014). A Federal Highway Administration report ("Service Lives of Highway Pavements," Public Roads, August 1971) gives the average surface life of concrete roads as 25 years and asphalt as 15 years. For city pavements, the vast number of 30 to 50-year-old concrete streets readily attests to their performance beyond the study figure of 25 years, while most asphalt streets would be hard-pressed to last for 15 years.

The causes of pavement failure are not different from those associated with the rest of the world; however, the severity of the causes here in Nigeria is at a high state due to increased traffic generation within developing satellite cities and towns. In Nigeria, of all the total length of road network available, only 19 % are in good condition while others are either in fair or bad conditions (WHO, 2015). The durability of Nigeria roads can be measured by the severity of the degree of cracks, patches and potholes, surface deformation and surface defects (Federal Highway Authority, 2001; Adlinge and Gupta 2013). According to Oke *et al*, (2013), these failures have contributed an annual loss of approximately two (2) billion dollars.

Furthermore, the service life capacity of roads does not only affect the economy of the country but additional, its effect is felt by the citizen, the government, and the environment (Okigbo, 2012). In Nigeria, road failure has contributed to the delay in travel time, increase traffic congestion, distorts pavement aesthetics, vehicle breakdown and most significantly, causes road traffic accident which has claimed lives and properties (Osuolale et al., 2012). The failure has contributed to noise and air pollution experienced in the commercial cities in Nigeria such as Lagos, Port-Harcourt, Kano, Abuja etc. Hence, Osuolale et al. (2012) state that "…there is a lot of concern about the state of disrepair of all categories of roads and the need to reappraise the construction materials and method used on roads within the country in order to check and overcome all the end result of highway pavement failures." this comment is worthy of noting and enhance proper actions to be taken. Likewise, considering the rate of road failure Nigeria road is rated by WHO as one of the deadliest roads in Africa with fatalities of 33.7 % per 100, 000 population yearly (Adedokun, 2015).

Putting into context the service life capacity requirement on Nigeria roads, there truly arise a need to take a paradigm shift, thus, the question remains what type of shift? Although over the years different shifts have been experienced in the construction of flexible pavement which relates more to soil stabilization, however, this has not totally resolved the failure experienced on Nigeria roads; which have been blamed on the very low bearing capacities of the subgrades available. Thus, the Nigerian government is in the state of shifting to concrete pavement based on the pros associated with it and availability of cement. Consequently, this paper presents some opinions on the necessary aforementioned factors to be considered in the success of concrete pavement use in Nigeria.

2. LITERATURE REVIEW

In Nigeria, 90% of all trade travels are done over the roads due to lack of an established rail system. A persistent lack of weight restriction and enforcement on trucks is pandemic all over Africa, and thus severe overloading of Trucks in Nigeria is prevalent. The Southern African Transport and Communication Commission (2001) outlines that where axle loading and traffic data is unavailable, the likelihood of overloading is high (see Table 1) this clearly shows the Average Daily Traffic Data generated by FERMA 2007 to be used as input parameters in pavement design depending on the location within the country. Traffic data for the major Federal Roads in Nigeria (FERMA 2007). The Table indicates; Major Federal Road, (Average Daily Traffic) ADT, Heavy Vehicles (%) and the ESAL for each road section*

Although, there are various factors affecting the performance of pavements around the world which have been mentioned in the introduction of this paper. However, this section takes a closer look at some critical factors which are crucial to the successfully improving the service life capacity of pavement type in Nigeria, this analysis is based on current problems which have been experienced in the design of flexible pavement as well as a qualitative analysis performed in South Africa. This the strength of both pavement types are clearly noted; where the strength of rigid pavement outshoots that of flexible pavement with regards to durability and longer pavement life. However, in other to improve the service life capacity of pavement in Nigeria, the following factors need to be considered.

Table 1. Traffic Data for Major Federal Roads in Nigeria (FERMA 2007)

MAJOR FEREDAL ROAD	AVERAGE DAILY TRAFFIC *(ADT)*	HEAVY VEHICLES *(%)*	ESAL
Sokoto - Illela	3000	3.33%	111.6
Kano – Kastina	5600	3.57%	221.6
Akwanga – Jos	4000	5.50%	235.1
Abuja – Akwanga	5700	4.39%	271.8
Bida – Abuja	2100	14.29%	307.2
Kano – Potiskum	4000	7.50%	314.8
Jos – Bauchi	7000	5.43%	406.5
Potisku – Maiduguri	5000	13.40%	694.2
Zaria – Kano	10000	7.00%	828.8
Abuja - Kaduna	8000	10.00%	922.5
Benin City – Onitsha	11500	7.65%	932.4
Lokoja – Abuja	9000	10.00%	932.3
Kaduna – Zaria	11000	8.36%	960.3
Port Harcourt – Aba	10000	9.90%%	1026.0
Ibadan – Ilorin	8900	21.35%	1928.0
Shagamu – Ibadan	8900	21.35%	1928.0
Shagamu – Benin City	22000	14.09%	3175.6
Lagos – Shagamu	40000	10.00%	4144.0

(Source: Maduagwu, 2014)

2.1 Design Consideration

The design of rigid pavement is similar to the design of a slab and beam construction supported by the underlying soil or bedrock. Yoder and Witczak (1975) noted that the early development of concrete pavements was built directly on subgrade regardless of the subgrade type or drainage conditions. However, as designs evolved, pavements were built over granular subbases to prevent pumping; the consideration for a thick base should be done with regards to the (Equivalent Standard Axle Load) ESAL of the roadway, and the prevalent climatic condition. Although, the interactive variable in concrete pavement design is usually unquantifiable with many challenging unknowns. Pavement engineers should ensure pavement thickness is set based on, precise load analysis and distribution and pavement soil bearing capacity when all necessary in-situ test has been performed. Most importantly, stresses in rigid pavement should be analysed properly to determine the fatigue life; hazardous effects such as curling and wrapping should be calculated so as to determine the maximum joint spacing. A report carried out on design of PCC pavement was recently performed for an offshore harbor project in Kuwait. The design was performed using a software workbench PCASE where simulation of the design factors was considered during the data input and processed to determine the optimum design Portland Cement Concrete (PCC) thickness as well as the underlying pavement thicknesses based on the Resilient modulus requirement for the design criteria considered. The design parameters considered were assumed for adverse conditions where the pavement will be subjected to marine load as well as imposed harbour loads. The report indicated that; the effective thickness of the rigid pavement considered should be 150mm on a cementitious base layer, with 16mm.

2.2 Material Quality – Mix Design of Concrete

Akpokodje (1986), in a study on the geotechnical properties of the subgrade soils situated within the South – Eastern Nigeria for road construction concluded that pavement failure appears to be more extensive on the outer lanes and pointed to the fact that all slow-moving heavy trucks and failures tended to use the outer lanes (except when overtaking). Arumala and Akpokodje (1987) noted that soil properties and pavement performance, on nine major roads within the Niger – Delta region performed poorly due to the constant seasonal flooding within the region, increased water table and reduced soil properties which do not meet up to acceptable specifications for base course or subgrade design material for construction. The overwhelming conclusion was little adherence to design standards had been followed, which was attributed to poor supervision by government officials and the lowering of the design specifications during construction as result of insufficient funds. They found that soaked CBR's of sub-grades and some base materials was found to be as low as 2% (the Nigerian standard soaked CBR for a base course is greater than 30) and mostly the roads did not have well-defined sub-bases. This is the principal reason why the entire length of the 45km Kolo – Junction – Ogbia road failed completely only two and half years after construction. The cause of failure on subgrade soils as noted by Ajayi, 1987 is as a result of presence of saprolite instead of the strong lateritic soils.

Norbert (2008), stated that careful selection of concrete materials and careful mixture design and proportioning is a key success with regards to durability and strength. The mix design of concrete should be taken from a standard laboratory test on a finite aggregate and cementitious material results. Although, chemical admixtures are used to prevent reaction with the concrete and the reinforcement in the presence of water. Supplementary cementitious materials should be considered when cost and performance are needed. The aggregate type selected should be based on the aggregate impact and crushing value depending on the load analysis of the expected traffic. Other material constituents important for the study should be; the aggregate absorption value, texture and shape as this will greatly improve the strength of the mix and prevent unnecessary pumping and excessive bleeding. Consequently, the mix design principle should be taken as specified given by (Mindes *et al*, 2003).

2.3 Construction Practice

The type of concrete design selected should meet the requirements for fresh and hardened concrete (ACI 211, 1991). The water-cement ratio should be so as to reduce shrinkage as failure would occur due to fatigue cracking and crushing. An optimized aggregate gradation should be selected as this also optimizes the water requirement for curing and hardening. Most importantly, is the workability of the concrete and the slump value, this should be taken from design considerations and not from in-situ conditions with regards to ease of material flow during construction. Proper batching of concrete should be done and adequate curing of concrete to ensure a good hardened mix and longevity of the pavement. If the prevailing groundwater is susceptible to sulphate attack, sulphate resistant cementitious materials should be considered. Dowel bars subject to corrosion should be properly coated with epoxy as this will greatly improve the cathodic reaction within the concrete; with proper insertion of joints where necessary. Wrapping and curling up of the pavement slab can be greatly improved by reducing the drying shrinkage and thermal deformation through the use of supplementary reinforcing fibre materials added to the mix such as steel fibres, and other polypropylene fibre materials.

2.4 Maintenance Culture

The durability of concrete pavement is dependent on the nature and type of maintenance culture imbibed. However, well-built pavements require less maintenance than asphalt pavement under similar traffic and environmental conditions (Norbert, 2008).

2.4.1 Routine tests and Performance Level

The maintenance of concrete pavement is a cumulative implementation of all necessary construction practices and routine tests performed for pavement distress data collection such as; wheel path rutting and roughness, pavement structural condition, pavement profile condition, pavement stiffness and load joint transfer (WSDOT, 2006). A number of useful instrumentation equipment that will aid a proper road maintenance check and riding performance; the locked wheel trailer and the Falling Weight Deflectometer (FWD).

2.4.2 Routine tests and Performance Level

The construction of a durable rigid pavement is dependent on the provision of adequate joint formed. The success of creating joints together with a timely resealing of joints and cracks will greatly prolong the life of the pavement and provide a good riding quality. Examples of sealants implemented; Hot Pour Sealants, PVC Coal tars, silicon sealants which last for a longer period can also be used depending on the cost estimates and crack width. Most importantly also is maintaining a proper drainage system on the pavement by reducing ponding of water which deteriorates the pavement surface. However, surface drainage should be provided in form of side ditches and adequate grade elevation of the vertical alignment in the design where the surfaces of the pavement should be designed to resist clogging (Norbert, 2008).

3. RESEARCH METHODOLOGY

The choice of pavement type is usually limited to the availability of funds and the geometric design parameters considered. Previously, no stringent consideration is given to prevailing environmental conditions, weather cooperativeness, availability of standard material specification and adequate construction practice to be implemented. Although, the use of rigid pavement in Nigeria or in the African continent has not gained so much interest because of the cost related to the production of cement and the curing time taken in constructing concrete pavement. Rigid concrete pavement type has a longer year of service (30-50 years) when compared to the commonly used flexible pavement 15-25 years), yet the issue of economics rules the selection of surfacing of pavement as most of the Africa countries are developing or underdeveloped. However, considering the present development in the availability of cement production in Africa with Nigeria producing the largest quantity of Cement, arise the implementation of concrete paving in the transportation sector to improve service life capacity of road pavements.

The methodology adopted in this study outlines the necessary parameters required to attain a sustainable transportation infrastructure development system in Nigeria, using principles of Social Life Capacity Assessment, Life Cycle Assessment and Life Cycle Cost Assessment theorems and correlating these parameters with each other by cross-matching and considering the positivity in terms of the advantages it will yield depending on the choice of pavement type assumed in the initial design phase. There are certain key points to be noted for efficient Service Life capacity improvement on choice of pavement type around the world with Nigeria as a case study. These parameters are however explained further.

3.1 Maintenance Culture

Highways are designed based on historic climate, however, during their design life they could well be subjected to very different climatic conditions and distresses. The cost of not taking this into consideration could be detrimental to the traffic design, public safety resulting in deterioration of the pavement structure, (Willay *et al*, 2008). In the case of Nigeria, experiencing harsh weather and excessive rainfall intensity pattern (During the wet season (average precipitation of 2,500mm/year), under cemented ditches between the dual carriageway and on both sides of the carriageway, are permanently waterlogged, resulting in the ingress of water into the sub-grade and base courses) has contributed to wind erosion/desertification, soil erosion, landslides and coastal flooding (Odjugo, 2005; Ighodaro, 2008; Maduagwu, 2014).The durability of pavement structures relies itself on the nature of the prevailing weather conditions which it is laid on. However, according to American Concrete Institute, extreme weather conditions can cause problems for concrete and asphalt pavements, especially winter weather. There is a substantial increase in moisture and precipitation during the cold season, like rain, ice, and snow. These elements, and other factors, greatly contribute to the natural wear and tear of roads and pavements, as well as, accelerated deterioration and degeneration.

Wet or otherwise slippery roads influence the road grip capacity of vehicles negatively, as most road users probably know from experience. Slippery roads may be caused by (excessive) rainfall, snow or (black) ice or by wet leaves in the autumn. In addition, Eisenberg (2004) stated that oil accumulated on roads during dry periods creates a thin film with rainwater. The extent to which this happens probably also depends on the road surface type. It is important to note that the two main climate parameters which are critical in road pavement design are temperature and precipitation. Abejide and Mostafa, 2017, investigated the effect of moisture content on HMA and noted that increase in moisture content in the underlying layer of HMA pavements results to increase in the strain of the individual layers culminating to a reduction in the structural carrying capacity of the pavement with increasing load cycles. Precipitation-induced road degradation is assumed to be significantly aggravated where average annual precipitation increases by 100 mm/day (Chinowsky *et al*, 2011).

The weather condition experienced in Nigeria has further contributed to the failure of flexible pavement; however, rigid pavement can be said to have the capacity to withstand such harsh weather conditions compared to flexible pavements, instead of depreciation in the underlying pavement layer bearing capacity as a result of increasing moisture, the strength of rigid pavement is rather increased on the opposite with increasing moisture as the moisture aids in further curing of the concrete with time especially where cementitious compound is composed of pozzolanic sulphate materials. On the contrary, should the site for the pavement be located in areas where the soil is stable with reduced rainfall, it will be more advantageous to select a flexible pavement considering cost, ease of construction and fewer construction methods without complexities (construction joints, expansion joint, etc.).

3.2 Riding Quality

Pavement roughness is an important indicator of pavement performance. A road user's perception on driving quality of pavement is primarily influenced by its roughness i.e. ease of riding. This implies that rougher roads usually increase the operating costs to both the travelling public and the commercial trucking industry (Rister & Graves, 2010). The international roughness index (IRI) is used to evaluate new and rehabilitated pavement conditions and for construction quality control/quality assurance purposes (Zhao et al., 2006). Riding quality can be used also to summarize the roughness quality that impacts vehicle response and is most appropriate when a roughness measure is desired that relates to the overall vehicle operating cost, ride quality and surface condition (Sayers and Karamihas, 1998). Roughness measurements are usually expressed in terms of meters per kilometre (m/km) or millimetres per meter (mm/m). The IRI is based on the Average Rectified Slope

(ARS). Pavement roughness, from the concrete road perspective, is not to be confused with pavement texture. Texture provides assurance that a pavement surface has adequate friction while roughness indicates the smoothness in the riding quality of the constructed pavement. Thus, the riding quality and noise control will be dependent on the requirement for strength and performance of the pavement while in service.

3.3 Vehicle Fuel Efficiency

Vehicle fuel consumption and emissions are two increasingly important measures of the effectiveness of sustainable transportation system (Sumitsawan *et al*, 2009). Consequently, various studies have revolved around fuel consumption in the vehicle used on highways. Although vehicle fuel consumption is not affected by just one factor, it's affected by various factors which including speed, acceleration-deceleration cycle, vehicle mass, mechanical conditions of the vehicle, ambient conditions and most importantly pavement surface conditions (Ardekani and Sumitsawan, 2010; Newcomb *et al*, 2010). Focusing on the pavement surface conditions, various studies (Taylor and Patten 2006; Sumitsawan *et al*, 2009; Jonsson and Hultqvist, 2008) have shown that in rigid pavement the vehicle fuel efficiency is high when compared with flexible pavement.

According to (Taylor and Patten, 2006), the saving in fuel used on rigid pavement range from 0.8 percent to 1.8 percent and even up to 3.1 percent depending on the seasoning (Winter, Summer, Spring or Autumn) when compared with asphalt roads, however, this study to a great extent considered other factors yet, the major focus was on the pavement surface type. Furthermore, a Canadian and Swedish study was conducted using heavy truck and passenger cars respectively. Results of the studies indicated that there was potential fuel saved in rigid pavements over flexible pavement (Fuel Efficiency Report 2004; Taylor and Patten, 2006; Jonsson and Hultqvist, 2008). Considering the fact that Nigeria is in a state of developing economic growth and thus, continually experiencing growth in the number of vehicles per population, there arises a need to consider alternative pavement surface type for vehicle fuel efficiency to be achieved and consequently reduce carbon footprints.

However, Newcomb et al, 2010 argues that instead of putting into consideration the pavement surface type, it is preferable to consider the smoothness of the surface whether it be flexible or rigid pavement. In addition, Newcomb et al, (2010) argue that asphalt surface is smoother; however, it needs to be well maintained for consistent smoothness. Overall, an optimal maintenance program needs to be maintained, be it rigid or flexible pavement, as this increases pavement smoothness which, consequently, reduce the fuel consumption by about 7 billion gallons annually, while an uneven road surface may increase fuel consumption by up to 12 percent (Fuel Efficiency Report, 2004; Newcomb *et al*, 2010). However, this is actually a food for thought for Nigeria roads and its maintenance strategies since flexible pavement is associated with fatigue rutting, bleeding and curling during hot temperate seasons; this condition will result in uneven pavement grade and increase fuel consumption.

3.4 Riding Quality

The Organisation for Economic Co-operation and Development (OECD) has introduced the concept of sustainability into the domain of project management. In many countries, environmental issues and energy consumption play an important role in the planning of highway projects (Fuel Efficiency Report, 2004). This is because environmental sustainability issues have been a centre of various researches, especially in construction industries. Environmental sustainability entails the reduction in pollution i.e. carbon footprint. This is one of the by-products from the operation of motor vehicle. In motor vehicles, CO_2 S_iO and CO are the by-products of the combustion process released to the atmosphere as a tailpipe emission, which is one of the greenhouse gases contributing to global warning.

Over the years various development has been made in the transportation sector to reduce its contribution to the global warming, these include improvement in vehicle shape, mass, engine size, tire quality and most recently, the pavement surface type is being considered. The aspect of the pavement type relates to the materials used in the construction. In a report by EUROBITUME (Fuel Efficiency Report 2004), it was stated that asphalt surfacing contributes less to greenhouse gas emission during construction, maintenance and operation when compared with concrete pavement. Further studies by Brown (2009) and Sumitsawan *et al*, 2009, have buttressed this fact with these statements "…that for every 1000kg of Portland cement, approximately 650kg of CO2 is produced while the carbon in the asphalt will never be released into the atmosphere..." and "…hot mix asphalt generates only 22 percent of the carbon footprint of the Portland cement concrete pavement". However, the aforementioned studies accounted for the CO2 released from the cement kilns in estimating the carbon footprint for PCC project without accounting for the CO2 released from the oil refineries during asphalt production.

Nevertheless, Sumitsawan *et al*, (2009) argue that the greenhouse gas emission during road operation could be substantial and may dwarf any generated effects during the production and construction phases and concluded that there is a larger potential saving in using PCC pavement over asphalt pavement when the design life of the pavement is considered. Furthermore, in flexible pavement construction cement still remains one of the major materials used as a soil stabilizer on weak subgrades, this strategy still questions the use of flexible pavement, making it non-environmentally friendly. Various material innovations have come in place to reduce the use of cement without compromising the strength such as Fly Ash as a stabilizer in concrete works and consequently, reducing the carbon footprint.

3.5 Service Life Capacity

Life Cycle Assessment (LCA) is an evaluation of pavement products from their inception, design, construction and maintenance (Santero *et al*, 2011). Further studies on Life Cycle Assessment (LCA) can be carried out to indicate the durable life span for an Asphalt pavement compared with a PCC rigid pavement. Life Cycle Assessment study is being integrated daily in different disciplines to achieve sustainable development growth which encompasses the road construction sector. Environmental impacts are studied and further tabled against all expected stages in the construction of a new Highway project and each stage is linked into another stage. The studies are carried out at the inception/development stage of the road construction since it's a crucial stage whereby if it fails or poorly designed, the road can be expected to have a shorter life span. One of the most difficult challenges facing the present society is the integration of human development activities and ecological-resource conservation (use of non-conventional materials in design and construction of infrastructure development). This challenge is particularly true of all phases of roads from construction to use to remove as all of these actions directly or indirectly interact and alter with the ecological systems (Forman *et al.*, 2003). According to Nnanna (2003), huge sums of money have been sunk into road development in Nigeria but, due to increase in traffic volume; and the demand for longer pavement route to places of work and residential areas, these roads are not in good shape or in existence. However, except for a country like South Africa, which has a good soil foundation, thus not necessary affected having 90 percent of the road network paved with asphalt. Yet, approximately 26 percent is in fair condition, 12 percent in poor/very poor conditions and the remaining are in good condition (Kannemeyer, 2013).

Although, Social Impact Assessment (SIA) cannot overlook that an investment project is initiated to support a larger plan, programme or policy. Hjelmbrekke *et al.* (2014) found that an alignment of project outputs with strategic goals happens to a certain extent in some projects, but it seems random and very dependent on individuals assuming broad responsibility'. The strategy (i.e. an overall policy of the financing party) must be supported by the activities at operational level (among other activities, investment projects). Policies constrain plans which constrain projects, and separate SIAs are typically conducted at these different levels. The assessment indicators to improve pavement service life capacity should be adapted to the actual level. When selecting indicators for an SIA of a project, the assessor (Government, community, public sector, professionals, expert minds and specialist) must bear in mind that the project is initiated in order to support an overall developmental policy.

Furthermore, to obtain a sustainable infrastructure, a simulation of all the input variables with respect to each individual input factor is performed. This is done simultaneously with the variables for Social Impact Strategic Plan (SISP); [weather conditions, riding quality, vehicle fuel efficiency, job creation, noise pollution, noise control and health and safety]. The eventual result obtained should align with life cycle sustainability assessment objectives (see Figure 1).

3.6. Life Cycle Sustainability Assessment

A Life-Cycle Sustainability Assessment (LCSA) to determine choice of pavement suitable to be designed for would be a function of the expectances from the summation of the probability of reliability indices obtained from Life Cycle Assessment, Life Cycle Cost and Social Life Cycle Assessment. SHR (2001), concluded that Life Cycle Cost Assessment must be carried out for any project. Hindrances to LCCA application or use appear to be the lack of information and data needed to support the analysis for assets management for pavement and bridges. LCCA entails; service cost preventive maintenance cost, operating cost, disposal cost, initial cost and service cost (Flannery et al, 2016).

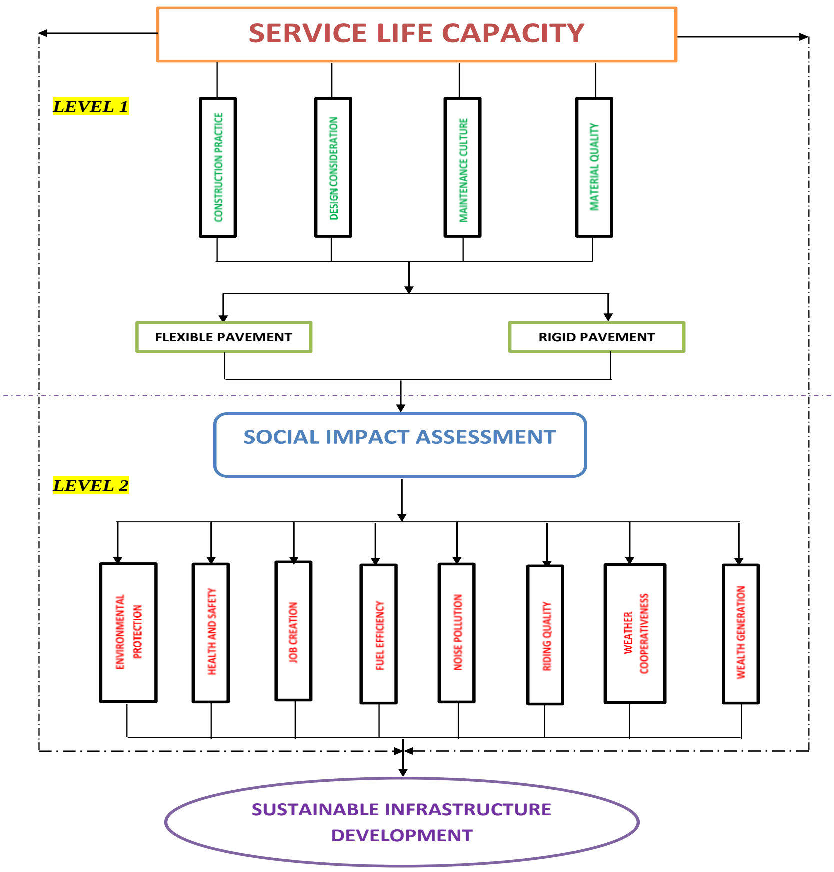

Figure 1: Research Paradigm for Strategic Service Life Sustainable Infrastructure

3.6 Life Cycle Sustainability Assessment

Life Cycle Sustainability Assessment (LCSA) used to determine the choice of pavement suitable to be designed for, would be a function of the outcome from the summation of the probability of reliability indices obtained from Life Cycle Assessment, Life Cycle Cost and Social Life Cycle Assessment as the variable input parameters. According to SHR (2001), Life Cycle Cost Assessment must be carried out for any project. Hindrances to LCCA application or use appear to be the lack of information and data needed to support the analysis for assets management for pavement and bridges. LCCA entails; service cost preventive maintenance cost, operating cost, disposal cost, initial cost and service cost (Flannery et al, 2016).

4. DISCUSSION AND FINDINGS

The design for a sustainable pavement considering the service life capacity of rigid pavement compared to the flexible pavement should be based on specifications given in the American code UFGS, UFC code manuals as well as the software provided for the design of the pavement in PCASE build 2.09. The PCASE pavement design thickness (x = 6 inches < 9 inches) should be assumed with a concrete strength (f_{cu} = 30Mpa < 20Mpa); with the use of steel fiber reinforced concrete mix, the steel fiber content for the specified concrete mix should be taken based on the concrete strength (x = 85 lb/yd^3 < 120 lb/yd^3) Table C-1 (UFC-3-250-04) with a deformed fiber reinforcement type. The proposed specification in TM 5-824-3/AFM 88-6 would result in a thinner pavement section. The use of steel fibre in the concrete mix is to provide additional load carrying capacity. The advantage of this will greatly reduce construction time and reduce challenges due to construction logistics, planning, and operation. The service life capacity is improved by the provision of steel fibre which helps to reduce crack propagation due to failure (fatigue cracking) that may arise as a result of serviceability limit state problems during the service life of the pavement. The essence of the steel fibre is to achieve an increase in the compressive strength of the pavement with a smaller section thereby saving materials and aggregate which can be used for other sections or other projects. This will result in less environmental hazard during the crushing and manufacture of gravel aggregate for the construction.

The choice of the design using reduced pavement section thickness is to enhance green construction and new methods in design and construction of rigid pavement using alternative construction material such as steel fibre to improve strength compared with the conventional cement and aggregate pavement mix which is time-consuming and expensive with very thick rigid pavement sections.

Although stakeholders have recommended the use of concrete pavement to rehabilitate the dilapidated Wharf-Apapa road in Lagos, the recommendation was made by a delegation from the Federal Ministry of Works, Power and Housing as well as the Nigerian Port Authority (NPA). Concrete roads will be a viable alternative for Nigeria in terms of quality and durability, and against the background of the incessant failure of bituminous roads (Ajayi 2016). Social Impact Assessment (SIA) related to social consequences that are likely to follow from specific policy actions or rigid pavement project development, particularly in the context of appropriate national, state, or provincial environmental policy legislation must be considered to execute a pavement type. However, social impacts related to socio-cultural consequences to human populations either public or private actions which may alter the ways in which people live, work, play, relate to one another, health considerations would be accounted for during the planning stage of the rigid pavement projects.

5. CONCLUSION

From the study conducted, it can be concluded that the service life capacity of any pavement type is dependent on prevailing factors within the environment it is to be constructed; such factors include; social impact, economic development, weather conditions, material properties design consideration etc., as previously mentioned (see Figure 1). Since concrete is known for its high strength modulus of elasticity and tends to distribute the loads applied over a relatively wide soil area, the choice of rigid pavement type looking at the prevailing climatic condition in Nigeria making the roads subjected to increased precipitation which makes it unsatisfactory for flexible pavement, but more efficient for rigid pavement since increasing moisture content results in hydration of the cementitious properties which makes rigid pavement to harden with increasing strength gain. Although, a major cause of failure on the Nigerian road is due to underestimated excessive traffic load which however overshoots the design traffic load and this causes 90% of most failed road sections (Campbell, 2009). Thus, concrete pavement could be much suitable for construction where strength is needed with increased traffic load due to its high modulus in resisting fatigue strain. In areas prone to increased rainfall intensity and swampy regions where flexible pavement will not be adequate to construct due to increased cost, it would be much cheaper and durable to construct a concrete pavement as concrete hydrates on reaction with water, with increased strength especially when water repellant additives are used. Concrete pavement will also account for increased load carrying capacity over a longer period of time 20 – 30 years compared to flexible pavements which will possibly last for 12 – 15 years. Furthermore, maximizing community involvement in the Social Impact Assessment (SIA) of new project development such as in Rigid Pavement as alternative to sustainable road pavement would promote accuracy in SIA and the capacity for the SIA to gain full impact.

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