

TITLE PAGE

**INVESTIGATION ON THE ECONOMIC AND LIFE CYCLE COST
BENEFITS OF CONCRETE OVER ASPHALT PAVEMENT (USING
ISIEKE EBONYI STATE, AS A CASE STUDY)**

B. ENG. PROJECT SUBMITTED

BY

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**IN PARTIAL FULFILMENT OF THE REQUIREMENT FOR THE
AWARD OF BACHELOR OF ENGINEERING (E.ENG) IN CIVIL
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TO THE

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CERTIFICATION

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DEDICATION

This work is dedicated to the creator of the whole universe, the Almighty God, He has been wonderful to me.

ACKNOWLEDGMENT

My profound gratitude to my loving parents Madam Rose and Emmanuel Nwankwoeke and Mr. Nwankwoeke Okechukwu who have always been a source of encouragement to me to see that I achieve my dreams.

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ABSTRACT

Life cycle cost analysis is a method for assessing the total cost of the facility ownership. It takes into account all cost acquiring, owning and disposing of a building, or building system. The cost of road construction consists of design expense, material extraction, construction equipment, maintenance cost, rehabilitation cost, salvage cost initial construction cost, fuel cost, time saving cost and operations cost over the entire service life of concrete over asphalt pavement. An economic analysis process known as Life Cycle Cost Analysis (LCCA) is used to evaluate the cost efficiency of alternative based on the Net Present Value (NPV) concept. It is important to evaluate the above mention cost – aspect in order to obtain optimum pavement life-cycle costs. However, pavement managers are often unable to consider each important element that may be required for performing failure maintenance tasks. The life cycle cost of concrete over asphalt pavement was investigated using Isieke Ebonyi State as a case study. The result obtained from the life cycle cost of both alternatives indicate that the concrete pavement has a longer service life than asphalt pavement and for 1km (kilometer) road length, the life cycle cost of the concrete pavement is lower by a value of 17.3million in naira than that of asphalt pavement in forty (40) years analysis period. The 1km (kilometer) concrete pavement is therefore adjudged as an economic viable alternative over asphalt pavement due to it relatively lower life cycle cost and higher service life and as a result must be given due consideration by prospective investors. Current Life Cycle Cost Analysis (LCCA) method are analysed in research. LCCA research will become more robust of improvement are made, facilitating private industries and government agencies to accomplish their economic aims.

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CHAPTER ONE

1.1 INTRODUCTION

A highway pavement is composed of a system of overlaid states of chosen processed materials that is positioned on the in-situ soil termed the subgrade. Its basic requirement is the provision of a uniform skid-resistant running surface with adequate life and requiring minimum maintenance, the main structural purpose of the pavement is the support of vehicle wheel loads applied to the carriageway and the distribution of them to the subgrade immediately underneath. If the road is in cut, the subgrade will consist of the in-situ soil. If it is constructed on fill, the top layer of the embankment structure are collectively termed the subgrade. (Martin Rogers et al 2013).

Highway pavement construction, maintenance and rehabilitation costs are rising dramatically. It is important for highway agencies to utilize tools and approaches that facilitate proper decision-making by applying economics and operations research such as Life-Cycle Cost Analysis (LCCA) to achieve economically reasonable long-term investments. LCCA is a method based on principles of economic analysis. It improves the estimation of the total long-term economic viability of different investment options. This method finds significant application in pavement design and management. A number of agencies employ the LCCA approach to estimate the economic feasibility of pavement designs over the long haul. Thus, it is very important for agencies to realistically evaluate pavement economics in order to provide suitable input to the LCCA. (Taylor et al. 2016).

As a concept, it was in the 1950s that benefit-cost analysis (BCA) was initially applied as a selection factor for various pavement design options. Then in the 1970s, LCCA principles started being implemented in some key projects at the local and national state levels for pavement design and pavement type selection.

Considering the mostly inadequate funding under normal circumstances, road authorities are consistently challenged with funding projects due to insufficient resource. Moreover, with the increasing demand for new road infrastructure, the demand for efficient management of old and new roads is on the rise as well, along with safety demands, accessibility and the implementation

of advanced traffic management systems for decreasing socio-economic costs by mitigating maintenance-related environmental effects, traffic issues, and losses. Maintenance backlogs nonetheless increase too. Road authorities thus emphasize more on better efficiency and lower expenses due to limited funds. Since maintenance expenditures normally comprise half the annual road infrastructure funds, it is very important to prioritize efficiency in road maintenance. Thus, with respect to road objects, life-cycle costs (LCCs) are regarded as having higher priority than simply investments. Hence, road authorities are expected to realize the importance of Life cycle cost agency (LCCA) and maintain a calculation system. LCCs are also deemed to be a restraint in road design selection or the assessment of tenders. When calculating LCCs, both road authority costs and costs of socio-economic nature should be taken into account. Road agency (authority) costs comprise expenses for planning, construction, design, maintenance, and rehabilitation. All these costs are usually the government's responsibility to cover using tax earnings. Socio-economic costs comprise of agency costs, user costs (e.g. delay costs, accident costs and vehicle operation costs), and environmental costs.

1.2 STATEMENT OF THE PROBLEM

The dramatic increase in traffic volume in built-up areas, such as the Capital road, Federal Trunk Roads of Nigeria results in more and more construction of new roads and modernization of old ones. Therefore, this requires further studies on how road pavement types are selected.

Road Authorities could make more informed and better investment decisions, because pavement type has a significant impact on future cost and service quality. Traffic growth, especially in heavy axle load can cause damage to pavements much quicker than expected, in turn causing more maintenance and thereby increasing agencies and users costs.

Pavement type choice is usually based on traffic level, soil conditions, atmospheric factors and costs. In many cases, the initial construction cost is the main consideration; the future maintenance and rehabilitation costs may sometimes be forgotten.

Life cycle cost analysis (LCCA) is a process of evaluating economic performance of a pavement over its entire life, sometimes known as whole cost accounting or total cost of ownership of firms.

It balance initial monetary investment with the long term expense and operating the pavement. According to the American Association of State Highway and Transportation Officials (AASHTO) Guide for the Design of Pavement Structures, life cycle costs “refer to all costs which are involved in the provision of a pavement during its complete life cycle”. That means that all pavement options are evaluated by taking into account different agencies and users costs.

Agencies costs include initial construction costs as well as future costs of rehabilitation, maintenance and facility operation. User costs are a result of many different issues, for instance increased delay costs, increased vehicle operating costs or charges in accident costs due to future maintenance actions.

All types of asphalt binding materials used in our country are imported with hard currency and its cost is becoming increasingly high from time to time. On the other hand cement materials have high potential of production in Nigeria and it is hoped that the price will decrease. Asphalt pavement requires heavy maintenance activities starting from early stages of its service life, but Cement Concrete as an Alternative Pavement Material Over Asphalt pavement in Arterial Roads of Nigeria (Isieke Ebonyi State); Hence, this study will try to address the problem and show economic advantages of using locally available resource for sustainable pavement construction. (AASHTO 2013).

1.3 AIM AND OBJECTIVES OF THE STUDY

1.3.1 AIM

The general aim of the study is to identify the sustainable and economical pavement material in arterial roads of Nigeria by making life cycle cost comparisons and economic analysis of Cement Concrete with Asphalt Concrete pavement materials in selected representative arterial roads of the Isieke Ebonyi State.

1.3.2 Specific objective;

- To identify the initial cost for both concrete and asphalt pavements.
- To identify the required types of life time maintenances for both concrete and asphalt pavements.

- To identify the varying costs related to different maintenances involved in concrete and asphalt pavements.
- To carry out economic evaluation of concrete and asphalt pavements on selected segments of roads in Nigeria for forty years and to determine which pavement type is more economical and sustainable.
- To draw conclusions and forward recommendations based on the findings of the study.

1.4 SCOPE

The primary objectives of road construction project planning are to optimize quality, cost and time. In Nigeria, this construction industry and its management is at developing stage, fulfilling these requirements is difficult and challenging. This research work therefore, focuses on one of the basic requirements i.e. cost. Hence, the scope of the study is restricted to the identification of Cement Concrete as an Alternative Pavement Material Over Asphalt Concrete in Arterial Roads of Nigeria;

The scope of the study is, therefore, limited to evaluation of two alternative pavement types based on life cycle cost and economic advantages for sustainable road construction projects. Environmental impact and societal benefits from this sustainable road construction projects will not be fully quantifiable in this study.

This research work started with problem identification, followed by literature review, formal and informal discussion with professionals in the federal road construction sectors, such as concrete and asphalt pavement

Concrete Pavement material against Asphalt Concrete material in trunk road of Isieke Ebonyi State roads of Nigeria. Literatures include magazines, books, journals, internet etc. In parallel with literature review, an in-depth desk study has been conducted to identify construction costs, maintenance costs, environmental impacts and road user benefits of each pavement material type. During the desk study, various documents such as design manuals of different countries, technical specifications, feasibility studies reports, Engineering design reports, correspondences, progress reports, completion reports, payment certificates, statements on final account, road asset management documents etc. has been critically evaluated. Whenever there is unclear primary data

or ambiguity during the desk study, further explanation or information has been obtained through informal interviews with professionals involving in road construction projects especially pavement or material Engineers, in order to maximize the clarity and to gain adequate understanding of the data for its use in analysis of cost of concrete over asphalt pavement, using Ebonyi State manual guide 2013.

The document search was intended to collect pavement design trends, values of initial/construction costs consumed and annual maintenance or rehabilitation costs allocated from some randomly selected upgrading and rehabilitation trunk type road construction projects which are completed/substantially completed.

Then analysis and discussion has been conducted based on the primary & secondary data obtained. Finally, conclusions have been drawn and recommendations forwarded based on the finding of the study and literature reviews. The study has been conducted on projects with high traffic volumes of Trunk type Federal Roads of Isieke Ebonyi State of Nigeria.

Life Cycle Cost Analysis provides a methodology for computing the cost of a product or service during its lifetime. It is used to compare competing design alternatives over the lives of each alternative, considering all significant costs and benefits, expressed in equivalent monetary units. For infrastructure assets such as roads, a large proportion of the total cost over the lifetime of these assets is incurred after construction, i.e. during their service lives. It is possible to avoid most of the “unknown” costs by introducing long-term costs into the pavement valuation processes instead of comparing only initial material and construction costs. (Akbar et al. 2012).

Analysis period of 40 years has been determined based on the recommendation of AASHTO 1993 and in order to utilize the full design life of concrete pavement for proper comparison of the two pavement type alternatives.

1.5 RELEVANCE OF THE STUDY

In the area of road construction, proper planning of projects is important to highway organizations (authorities) as their construction program outlines how highway funds are to be spent over time and to be sustainable in its serviceability for the comfort of road users, any deviation from the established program often brings a quick response from the public, the press, and politicians. When

this occurs, the highway organization loses creditability. On the other hand, if a highway organization can produce realistic program estimates that it is able to attain, then the image of the agency is enhanced.

Therefore, it is the responsibility of the Authorities to make an accurate project planning in the selection of economical pavement materials for the construction of sustainable roads for allocation of justifiable budgets. Thus beneficiaries of this research are;

- The implementing authorities (Ebonyi State minister of works)
- consulting and construction firms plus practicing Engineers,
- Educational institutions, which use the information for academic purposes,
- Investors to focus on manufacturing of ready mix concrete for pavement works.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 OVERVIEW OF THE STUDY

Transport and mobility are essential for economic and social development. For this reason, developed countries have devoted considerable resources to the development of high-quality transport networks which need to be adequately maintained. Current road construction methods lead to significant maintenance requirements, which can only be met at a very high cost. The continued growth in road traffic and axle loads and the pressure to restrain government spending put growing pressures on road authorities to come up with new solutions. At the same time, the cost to economics due to congestion and disruption during road works on high volume roads has become unacceptably high.

There are growing pressures for long-life road infrastructures that require minimal maintenance. Pavements are the critical elements of an efficient highway transportation system for moving people and goods. Without well-performing pavements, the transportation infrastructure cannot effectively function, road users suffer (in terms of increased costs, travel time, and unsafe roads) and the overall economy suffers (in terms of higher costs for goods and commodities).

Modern societies cannot function without mobility, and mobility requires well-performing pavements. In recent years, innovation in the road sector has focused on economic and organizational structures, while changes in road paving techniques have been much less dramatic. Rather, they have at best been incremental. Yet, in order to optimize national highway budgets, whole-life costing methods are increasingly used to determine how, where and when to best spend budget funding on road construction and maintenance. Within this framework, the shift to full maintenance contracting has helped reduce costs, and the adoption of long-term contracts has helped establish an environment in which the development of more durable pavement types could be stimulated.

Therefore, long-lasting pavements that are safer, smoother, and environmentally sensitive and can be cost-effectively constructed and maintained are an important part to modernize the

Nigeria transportation system. In Ethiopia, billions of ETB are spent every year to construct, maintain, preserve, and rehabilitate the Nation's highway pavement infrastructure.

The accumulated investment in our roadway pavements is above billion for the last 16 years of Road Sector development program phase (RSDP). This investment needs to be protected and managed efficiently so that future generations of our citizens can have high standard infrastructure which is to be one of the best highway systems in Africa and to enjoy the benefits of it. (Francis et al. 2016)

Initial cost of construction, maintenance cost of pavements and road user costs play major role for deciding which pavement will be more economical. There is no intensified life cycle cost comparison research conducted in this regard in Nigeria, but various studies have been conducted worldwide in different countries in this subject matter through different researchers.

It is becoming increasingly apparent that a host of human activities and development practices are negatively affecting the economic, environmental and social well-being of the planet, putting future generations of human being, as well as other species, at risk. Confronted with this reality, stakeholders in the pavement industry are being challenged to adopt practices that maintain economic vitality while balancing environmental and social needs. (Francis et al. 2016).

At the same time, stakeholders are facing other challenges: pavements are aging and deteriorating; 26% of the paved road system are not in a good condition. Traffic volumes and axle loads continue to increase, putting more demands on the already stressed pavement system in the country. Road way authority budgets continue to fall short of funds needed to substantially improve pavement conditions. The trend and budget allocation attention for pavement condition improvement, comparing with new projects, is very poor in a developing country like Nigeria.

The people responsible for the management, design, construction, maintenance and rehabilitation of the deteriorating network of pavements are overwhelmed, recognizing that the current approach to solving problems inherent in the countries pavement infrastructure is not sustainable. What is needed is a new approach, the implementation of truly sustainable pavement solutions that result in reduced cost over the life cycle, lessened environmental impact and enhanced societal benefit. The main purpose of this research is to evaluate the life cycle cost benefit of concrete over asphalt pavements.

2.2 DEFINITION OF SOME MAJOR TERMS

Concrete is basically a mixture of two components: aggregates and paste. The paste, comprised of Portland cement and water, binds the aggregates (usually sand and gravel or crushed stone) into a rocklike mass as the paste hardens because of the chemical reaction of the cement and water. Design Manual 2013 required a 28-day characteristic compressive strength of 30, 35 or 40 MPa for pavement construction. However, the 28-day concrete flexural strength is a principal design factor. The suitable value for road pavement construction is 40 Mpa.

2.2.1 Concrete pavements: (also called rigid pavements), as the name implies, are Concrete and very strong in compression. The strength of the pavement is contributed mainly by a concrete slab, unlike asphalt pavements where successive layers of the pavement contribute cumulatively. The rough surface required for an adequate resistance to skidding in wet conditions can be provided by dragging stiff brooms transversely across the newly-laid concrete or by cutting shallow randomly spaced grooves in the surface of the hardened concrete slab.

As the name 'Concrete' implies, the deflections under a loaded wheel are very small compared with the deflections observed in flexible pavements and the stresses within the underlying sub-base and subgrade are also comparatively small. Concrete pavements therefore deteriorate through quite different mechanisms from those that affect asphalt pavements. This constitution implies the following advantages:

It is feasible to design Concrete pavements for longer design lives, up to 60 years.

Little maintenance is generally required

Concrete pavement deforms less under traffic as compared to asphalt pavements

A relatively thin pavement slab distributes the load over a wide area due to its high Concretively. Localized low strength sub-grade materials can be overcome due to this wider distribution area. Concrete is very resistant to abrasion making the anti-skidding surface texture last longer.

In the absence of deleterious materials (either in the aggregate or entering the concrete in solution from an external source), unlike with asphalt pavements, concrete does not suffer

deterioration from weathering. Neither its strength nor its stiffness material affected by temperature changes.

2.2.2 Asphalt concrete can be described as a combination of bitumen and aggregates which are mixed together, spread and compacted while hot, to form a pavement surface. The strength of asphalt is derived from friction between the aggregate particles, the viscosity of the bitumen under operating conditions and the cohesion within the mass resulting from the bitumen itself and the adhesion between the bitumen and aggregate.

In reality asphalt concrete is visco-elastic in nature due to the bitumen in the mixture. However, at the normal operate rates and magnitude of loading and temperature, asphalt may be considered as an elastic isotropic material.

Initial cost is generally the major factor in deciding the type of the pavement in design. The Planners often think that flexible pavement is cheaper than Concrete pavements. In fact this is not always the case. In the last decade the price of bitumen which is the main ingredient of flexible pavement has increased because of the increase in crude oil prices. However the Concrete pavement's main ingredient cement price is relatively stable

2.2.3 Life Cycle Cost Analysis; means a process for evaluating the total economic worth of a usable project segment by analyzing initial costs and discounted future costs, such as maintenance, user costs, reconstruction, rehabilitation, restoring and resurfacing costs over the life of the project segment.

According to the American Association of State Highway and Transportation Officials (AASHTO) guide for the design of pavement structures, life cycle costs “refer to all costs which are involved in the provision of a pavement during its complete life cycle”. That means that all pavement options are evaluated by taking into account different agencies' and users' costs. Agencies' costs include initial construction costs as well as future costs of rehabilitation, maintenance and facility operation. User costs are a result of many different issues, for instance increased delay costs, increased vehicle operating costs or changes in accident costs due to future maintenance actions.

Life Cycle Cost Analysis provides a methodology for computing the cost of a product or service during its lifetime. It is used to compare competing design alternatives over the lives of each alternative, considering all significant costs and benefits, expressed in equivalent monetary units. For infrastructure assets such as roads, a large proportion of the total cost over the lifetime of these assets is incurred after construction, i.e. during their service lives. It is possible to avoid most of the “unknown” costs by introducing long-term costs into the pavement valuation processes instead of comparing only initial material and construction costs.

Pavement type decisions are usually based on traffic level, soil conditions, atmospheric factors and construction costs. Usually, construction cost is the main consideration; the future maintenance and rehabilitation costs may be forgotten. (Velado, M. et al. 2012).

2.3 EXPERIENCE AND PRACTICES OF LIFE CYCLE COST ANALYSIS (LCCA)

2.3.1 Practices from Asphalt Associations

In 2004, the Asphalt Pavement Alliance (APA) released a position paper that concluded that pavement type selection should be a road user-oriented process, not an industry-oriented process. It states that the system used to select pavement type should be objective, defensible, understandable, and based on historical records, primarily driven by economics and periodically reviewed.

APA supports the use of life-cycle cost analysis in the decision making process and recommends the methodology developed by the Federal Highway Administration (FHWA) in Demonstration Project. The Net Present Value (NPV) is used for the purpose of comparing alternatives. Initial costs, maintenance costs, and salvage value are recommended for consideration in the life-cycle cost analysis. APA recommends a 40-year analysis period when comparing asphalt with concrete pavements. APA states that asphalt pavements possess many advantages when compared with concrete pavements including low initial cost, low maintenance costs, flexibility and speed of construction, the ability to handle heavy loads, a long life, and complete recyclability.

APA conducted another study in 2005 to determine the average service life of flexible pavements to reach an unacceptable surface condition. Researchers considered six types of distresses in the analysis including fatigue cracking, longitudinal cracking in the wheel path area and longitudinal cracking outside the wheel path area, transverse cracking, rut depth, and smoothness measured by the International Roughness Index (IRI). Data for the analysis were extracted from the Long-Term Pavement Performance (LTPP) database. The median age of the 643 sections considered in the study was 17 years with 109 sections that were older than 20 years. An analysis to determine the probability of failure was performed for each distress type. According to the study, the expected service life to a moderate distress level exceeds 20 years for all distresses.

2.3.2 Practices from Concrete Associations

The American Concrete Pavement Association (ACPA) states that concrete pavements are a better choice than asphalt pavements because they have advantages in several areas including safety, durability, smoothness, versatility, and value. On safety, it provides better visibility, reduced wet spray since concrete never ruts, and provides the best traction grip. On durability, concrete hardens over time, and outlasts flexible materials since their average lifespan is 30 years. On smoothness, concrete stays smoother longer, creating safer, comfortable transportation surfaces and saving fuel. On versatility, concrete pavements can be; 1) designed to last from 10 to 50 years, 2) used to rehabilitate old asphalt pavement using white topping, or 3) used to rehabilitate a worn concrete pavement. On value, concrete pavements provide the best long-term value due to their longer life, they are easy to repair, and they can be built and opened to traffic in less than 12 hours.

In 2002, ACPA published a guide for comparing alternate pavement designs using LCCA. The guide describes the LCCA process factors that influence the results including agency costs (initial cost, maintenance and rehabilitation costs, and salvage value), user costs (delay of user-costs, roadway deterioration costs, and accident crash cost), discount rate, selection of rehabilitation activities, use of comparable sections, and length of the analysis period. Present worth (PW) and the equivalent uniform annual cost (EUAC) are mentioned as economic indicators used to express LCCA results. APA recommends EUAC because all costs are expressed in terms of an annual

cost over the analysis period. The guide also presents a brief summary of life-cycle cost and performance studies conducted with historical data in Michigan, Minnesota, Iowa, Florida, Tennessee, South Dakota, Utah, and Georgia. According to these studies, concrete sections lasted between 1.6 and 2.6 times longer than the asphalt sections and were from 14 percent to 250 percent more effective than the asphalt pavements.

2.3.3 Experience from the U.S. Department of Transportation, Federal Highway Administration

In 1998, the Federal Highway Administration (FHWA) published an Interim Technical Bulletin with recommended procedures for conducting life-cycle cost analysis (LCCA) of pavements.

The bulletin discusses how to address alternative pavement design strategies, length of performance periods and activity timing, agency costs (initial cost, maintenance and rehabilitation cost, residual value), and user costs (delay costs, vehicle operating, and crash cost) in LCCA. The Net Present Value is proposed as the economic indicator for comparing alternatives. The Federal highway Administration (FHWA) encourages risk analysis. A sensitivity analysis is recommended as a minimum to study the impact of the individual outputs on LCCA results. The discount rate is one of the major factors considered in the sensitivity analysis. The use of simulation techniques incorporated into LCCA such as Monte Carlo, is recommended to account for the variability of the input values and their influence in the results of the analysis.

In 2002, the office of Asset Management at the Federal Highway Administration (FHWA) published a Life-Cycle Cost Analysis Primer. The primer was intended to provide background information to evaluate infrastructure investment alternatives. The LCCA approach considers total user and agency costs when comparing alternatives. The application of Benefit Cost Analysis (BCA) to account for benefits in the comparison of alternatives is discussed in the primer. If expected benefits provided by the alternatives under comparison are different, then BCA is considered more appropriate than LCCA. A description of the LCCA process steps is included with a discussion on how to establish design alternatives, determine activity timing, estimate costs (agency and user), compute life-cycle costs, and analyze the results. The use of

the equivalent uniform annual cost or the present value is recommended as economic indicators to compare alternatives.

2.4 TYPES OF CONCRETE PAVEMENTS

According to the American Concrete Pavement Association, concrete pavement can be classified into three types: jointed unreinforced concrete pavement (JUCP), jointed reinforced concrete pavement (JRCP), and continuously reinforced concrete pavement (CRCP). This classification was done based on the joint spacing and use of reinforcement.

2.4.1 Jointed Unreinforced Concrete Pavement

In Jointed Unreinforced Concrete Pavements (JUCP), the pavement consists in an unreinforced concrete slab cast in place continuously and divided into bays of predetermined dimensions by the construction of joints. The bays dimensions are made sufficiently short (usually 15 times the slab thickness) so as to ensure that they do not crack. The bays are linked together by tie bars, the main function of which is to prevent horizontal movement (i.e. the opening of warping joints) and thus ensure load transfer through aggregate interlock.

2.4.2 Jointed Reinforced Concrete Pavement

In Jointed Reinforced Concrete Pavements (JRCP) the pavement consists generally in a cast in place concrete slab divided in reinforced concrete bays separated by joints at every 25 m. The reinforcement is made to prevent developing cracks from opening. This allows designing much larger bays than with JUCP. The bays are linked together by tie bars to prevent horizontal movement and thus ensure load transfer through aggregate interlock. The longitudinal reinforcement is the main reinforcement. A transverse reinforcement though not absolutely necessary in most cases is usually added to facilitate the placing of longitudinal bars.

Jointed reinforced concrete pavement, or JRCP, is distinguished from JUCP by longer slabs and light reinforcement in the slabs. The slab steel content is typically in the range of 0.10–0.25 percent of the cross-sectional area, in the longitudinal direction, with less steel in the transverse direction. This light reinforcement is often termed temperature steel

2.4.3 Continuously Reinforced Concrete Pavement

Continuously reinforced concrete pavement, or CRCP, is characterized by heavy steel reinforcement and an absence of joints. Much more steel is used for CRCP than for JRCP, typically on the order of 0.4–0.8 percent by volume in the longitudinal direction. Steel in the transverse direction is provided in a lower percentage as temperature steel

Continuously Reinforced Concrete Pavement (CRCP) is made of a cast in place reinforced concrete slab without joint. The expansion and contraction movements are prevented by a high level of sub-base restraint. The frequent transverse cracks are held tightly closed by a large amount of continuous high tensile steel longitudinal reinforcement.

Basically, the use of the different types of Concrete pavement is as follows:

JUCP is suitable for all levels of traffic, whenever the risk of sub-grade movement is low.

JRCP is suitable for all levels of traffic and is used when the risk of settlements of the sub-grade cannot be neglected.

CRCP shall basically be considered only for rather high design traffic (>30 million ESAL). They can also be included for less heavily trafficked schemes where the advantage of lower maintenance throughout the design life may be worthwhile. They are particularly suitable where settlement of the sub-soil is expected (Martin Rogers et al. 2013).

2.5 MATERIALS FOR CONCRETE PAVEMENT

Careful selection of concrete materials and careful mixture design and proportioning, combined with good design and construction practices, is a key contributor to success.

2.5.1 Cementitious Materials

Portland cements are hydraulic cements composed primarily of hydraulic calcium silicates. Hydraulic cements set and harden by reacting chemically with water. During this reaction, called hydration, cement combines with water to form a stone like mass, called paste. When the paste (cement and water) is added to aggregates (sand and gravel, crushed stone, or other granular material) it acts as an adhesive and binds the aggregates together to form concrete, the world's most versatile and most widely used construction material.

Hydration begins as soon as cement comes in contact with water. Each cement particle forms a fibrous growth on its surface that gradually spreads until it links up with the growth from other cement particles or adheres to adjacent substances. These fibrous build up results in progressive stiffening, hardening and strength development. The stiffening of concrete can be recognized by a loss of workability that usually occurs within three hours of mixing, but is dependent upon the composition and fineness of the cement, any admixtures used, mixture proportions, and temperature conditions. Subsequently, the concrete sets and becomes hard.

2.5.1.1 Portland Cement

Different types of Portland cement are manufactured to meet various normal physical and chemical requirements for specific purposes. Portland cements are manufactured to meet the specifications of ASTM C 150, AASHTO M 85, or ASTM C 1157. ASTM C 150, Standard Specification for Portland cement, provides for eight types of Portland cement using Roman numeral designations as follows: (William James Wilde, et al. 2013).

Type I Normal

Type IA Normal, air-entraining

Type II Moderate sulfate resistance

Type IIA Moderate sulfate resistance, air-entraining

Type III High early strength

Type IIIA High early strength, air-entraining

Type IV Low heat of hydration

Type V High sulfate resistance

AASHTO M 85, Specification for Portland cement, also uses type designations I through V for Portland cement. The requirements of M 85 are almost identical to ASTM C 150. AASHTO specifications are used by some state departments of transportation in lieu of ASTM standards. ASTM C 1157, Performance Specification for Hydraulic Cements, provides for six types of Portland cement as discussed under “Hydraulic Cements” below. A detailed review of ASTM C 150 and AASHTO M 85 cements follows.

Type I Portland cement is general-purpose cement suitable for all uses where the special properties of other types are not required. Its uses in concrete include pavements, floors, reinforced concrete buildings, bridges, tanks, reservoirs, pipe, masonry units, and precast concrete products.

Type II Portland cement is used where precaution against moderate sulfate attack is important. It is used in normal structures or elements exposed to soil or ground waters where sulfate concentrations are higher than normal but not unusually severe. Type II cement has moderate sulfate resistant properties because it contains no more than 8% tricalcium-aluminate (C₃A). Sulfates in moist soil or water may enter the concrete and react with the hydrated C₃A, resulting in expansion, scaling, and cracking of concrete. Some sulfate compounds, such as magnesium sulfate, directly attack calcium silicate-hydrate. Use of Type II cement in concrete must be accompanied by the use of a low water to cementitious materials ratio and low permeability to control sulfate attack (William James Wilde, et al. 2013).

Type III Portland cement provides strength at an early period, usually a week or less. It is chemically and physically similar to Type I cement, except that its particles have been ground finer. It is used when forms need to be removed as soon as possible or when the structure must

be put into service quickly. In cold weather its use permits a reduction in the length of the curing period.

Type IV Portland cement is used where the rate and amount of heat generated from hydration must be minimized. It develops strength at a slower rate than other cement types. Type IV cement is intended for use in massive concrete structures, such as large gravity dams, where the temperature rise resulting from heat generated during hardening must be minimized. Type IV cement is rarely available.

Type V Portland cement is used in concrete exposed to severe sulfate action; principally where soils or ground waters have high sulfate content. It gains strength more slowly than Type I cement. Sulfate concentrations requiring the use of Type V cement. The high sulfate resistance of Type V cement is attributed to low tricalcium-aluminate content, not more than 5%.

2.5.1.2 Supplementary Cementitious Materials

Supplementary cementitious materials, or mineral admixtures, include fly ash, slag, and silica fume, as well as other materials. Fly ash and slag are commonly used in pavements.

Blended cements are produced by intimately and uniformly inter-grinding or blending ordinary Portland cement (OPC) with one or more supplementary cementitious materials (SCMs). Most SCMs, such as ground granulated blast-furnace slag (GGBFS) or fly ash (FA), are industrial by-products. These materials are generally not used as cements by themselves, but when blended with OPC, they make a significant cementing contribution to the properties of hardened concrete through hydraulic or pozzolanic activity.

Typically, these materials retard early strength gain of concrete, but improve the ultimate strength and durability. Overall heat of hydration and the rate of heat buildup are both reduced. Workability is improved, and the concrete surface is often easier to finish. SCMs are increasingly used in concrete because of following benefits:

Reduction of economic and environmental concerns by utilizing industrial wastes, reducing carbon dioxide emissions, and lowering energy requirements for OPC clinker production; and

Improvements in concrete properties, such as workability, impermeability, ultimate strength, and durability, including enhanced resistance to alkali-silica reactions, corrosion of steel, salt scaling, delayed ettringite formation, and sulfate attack .

Ebonyi State of Nigeria, most blended cements used for pavement concrete contain 20% to 35% Ground Granulated Blast Furnace Slag (GGBFS). In addition, 15% Class C fly ash is often employed together with the blended cements to improve concrete workability and further reduce cost. The cementitious material (CM) containing fly ash, slag, and Portland Cement (OPC) were defined as ternary cement. If a CM consisted of only fly ash and OPC, it was defined as binary cement.

As discussed above, most SCMs are byproducts from other industries that beneficially react with Portland cement to enhance the performance of concrete. The effective use of SCMs reduces not only the amount of Portland cement required but also the need to dispose of what otherwise would be industrial waste.

The two most commonly used SCMs in paving concrete are fly ash and slag cement. Fly ash is a byproduct of burning pulverized coal for the generation of electrical power. The rock embedded in the coal melts in the furnace and is carried up the stack in the flue gases. As it rapidly cools, small glassy spheres are formed that are collected before the flue gases are emitted to the air. Because of the small size, glassy form, and chemical composition of the ash, it dissolves and reacts with the cement paste to contribute to the performance of the mixture. About 63 million tons of fly ash were produced in the United States in 2009, of which about 12 million tons were used either to make cement or in concrete.

Fly ash is currently specified in AASHTO M 295/ASTM C 618 in two classes based on the chemical composition. The differences are generally influenced by the source of the coal. In general, Class C fly ash is higher in lime content (CaO) and tends to be more reactive at early ages than Class F. The higher CaO content is beneficial for early strength gain but can have negative effects on alkali-silica reactivity and sulfate resistance. It should be noted that the specification for fly ash is broad and that two ashes from different sources, albeit of the same class, are likely to perform very differently; therefore, performance testing should be conducted to determine if the chosen fly ash is behaving as desired. Dosage of fly ash is typically between

15 and 40 percent by mass of cement. The amount of fly ash that can be used is often limited by concerns of delayed setting times and lower early strength gain. In some cases, there may be a potential for undesirable incompatibilities and a perceived increase in the risk of salt scaling. Judicious increases in dosage can be accommodated with attention to detail in mix proportioning and construction workmanship. Some factories use coal in our country, but byproduct collection and testing for fly ash is not yet practiced.

Slag cement, formerly known as ground granulated blast furnace slag (GGBFS), is the material left after extraction of iron from iron ore. When quenched from the molten state and ground to the fineness of cement, it is an extremely effective SCM. Slag cement is specified by ASTM C 989, and about 3 million tons are used in concrete in the United States every year. It is generally used in pavements in dosages up to 50 percent but is limited by concerns of early strength gain, especially when placed during cooler ambient temperatures, and scaling resistance. As with fly ash, usage tends to be regional because of limitations on the cost effectiveness of transporting it long distances. But slag cement is not available in Nigeria currently to consider for our cost comparison (William James Wilde, et al. 2013).

2.6 HISTORICAL BACKGROUND OF THE STUDY

The American Association of State Highway Officials (AASHO) introduced the concept of life-cycle cost-benefit analysis in its “Red Book” in 1960. The LCCA was introduced for highway investment decisions, and as such, formed the notion of economic evaluation of highway upgrades during the planning stage. The next progress step was made by Winfrey who combined data available on the cost of vehicle operations in a system to be utilized when highway planners are developing life-cycle costing processes. Moreover, two projects in the 1960s introduced the utilization of LCC principles for pavement type selection and pavement design. In the first project, the Centre for Highway Transportation Research and the Texas Transportation Institute (TTI) developed the Flexible Pavement System (FPS), a computer-based approach for analyzing and rating alternative flexible pavement designs through the overall life-cycle cost. The second project was by the National Cooperative Highway Research Program (NCHRP), which examined the promotion of the LCCA concept. Subsequently, the Concrete Pavement System (RPS) was

developed by Texas DOT, which is identical to FPS with regard to how Life-Cycle Cost Analysis of Concrete pavements is carried out. RPS also ranks alternative designs according to their total life-cycle costs.

The use of LCC concept is supported in the different AASHTO Pavement Design Guide editions, which also include detailed discussions regarding costs that should be considered in LCCA. The current study presents an overview of the basic life-cycle costing theories, with explanations of the various user and agency costs associated with highway pavement projects, as well as the discount rates and economic feasibility of systems.

CHAPTER THREE

3.0 RESEARCH DESIGN AND METHODOLOGY

The aim of the research was to identify the sustainable and economical pavement material in arterial roads of Nigeria by making life cycle cost comparisons and economic analysis of Concrete with Asphalt pavement materials in selected representative roads of Isieke Ebonyi State of Nigeria; considering asphalt pavement as a base case and project case of concrete pavement for comparison. The research design and methodology followed towards this end are discussed as follows.

A comprehensive literature review was made to understand the previous efforts, practical situations which include the review of textbooks, design manuals, commercial websites, previous studies by different professionals in different countries, periodicals and academic journals, seminar, conference and research papers.

3.1 MAIN RESEARCH

In this research, two pavement section of 1kilometer span road way in Isieke Ebonyi State was considered using life cycle cost analysis methodology and the test was carried out by comparing concrete and asphalt pavement.

A two pavement behavior scenarios was built: one for asphalt pavement and the other for concrete pavement.



Plate . 3.1 Concrete pavement



Plate 3.2 Asphalt pavement

LCCA applied here includes all costs that are involved in the manufacture and use of the product during its lifetime; it was decided to compare alternatives by using the Present Worth method. A more detailed description of LCCA can be found in chapter 2.

The components of LCCA were divided into two categories, agencies' costs and user costs. Agencies' costs include initial construction, rehabilitation and maintenance costs. Others costs, such as engineering design and land acquisition, were not considered. User costs such as vehicles operating costs, accident costs, discomfort costs etc. were considered equal for both pavement types. The only user costs to be considered will be fuel consumption costs and straight light requirement costs, because other data for user costs are difficult to collect and quantify due to lack of availability.

3.1.1 Data Collection

Traffic data were collected from Ebonyi State ministry of works historic data from manual. I took initial traffic data annual average daily traffic (AADT) from those manual for each specific road segment.

Construction material, labor and machinery unit costs were taken from current market values during the time of data collection, November 2021.

3.1.2 Analysis Period

Experience in the US shows the life of concrete pavement is often more than 20 years, while the life of asphalt pavement in Ethiopia is around 15 to 20 years, depending, of course, on traffic intensity and type of surfacing applied. The Federal Highway Administration (FHWA) recommends an analysis period of at least 35 years. An analysis period of 40 years was chosen for this research so that it could include full design period for concrete pavement, depending on the traffic level.

3.1.3 Discount Rate

Discount rate is used to convert the future benefits and costs of projects to present value. The higher the discount rate, the lower the net present worth of future costs will be. Thus, higher rates render initially expensive projects less profitable, while lower rates render them more so. A discount rate of 10% was used in this study as recommended by Ministry of Finance for evaluation of project feasibilities in Ebonyi State.

3.1.4 Traffic Analysis and Pavement Design

Traffic analysis and forecast were conducted using the applicable trend of traffic projection practices of the country. Two different traffic classes were selected for equivalent pavement design works for the two alternative pavement types.

Assessment was made on the existing pavement design type selection practices and conditions in our country in relation to international practices. Equivalent pavement design works were carried out for the two pavement alternatives using different traffic volumes based on the traffic analysis data.

3.1.5 Project Data Used

A 1 km length and 7.3 m width representative arterial road Ebonyi State were chosen from the five out let roads at the out skirts of Abakaliki the two alternative pavement options.

3.1.6 Data Analysis

It is the part and parcel of the main research to integrate and make analysis of the collected and computed data to come in to picture of this research. Hence, the following core tasks were carried out in the data analysis scheme.

The Present Worth method was used for cost comparison and economic analysis purpose.

Initial cost estimates were carried out for each alternative pavement structure based on current market rates of each specific cost components.

Life cycle maintenance and rehabilitation costs were adopted from international practices with some modifications to be suited for our specific country. User benefits and sustainability issues were assessed in this study. Cost comparison and economic analysis of concrete and asphalt pavement roads were conducted. The results were presented in Tables and chart form and interpretation and discussion were made on the research findings. Based on the findings conclusions are drawn.

CHAPTER FOUR

RESULT AND DISCUSSION

4.1 RESULTS

During the course of the research, certain data valuable to the research were sourced, processed and analyzed with the outcome used as basis for evaluating the economic and life cycle cost of Concrete over asphalt pavement at Isieke Ebonyi State, this data are presented in the Table below:

Table 4.1a Summary of Initial Construction Cost of 1km Concrete Pavement at Isieke Ebonyi State (Sourced and adjusted from Ministry of Works Ebonyi State).

Item No	Description	Total Cost (Naira)
1	Sub-grade level	3,240,000.00
2	Sub-base level	4,724,000.00
3	Concrete Pavement	48,728,000.00
4	Texturing and Curing	640,740.00
5	Joints	80,480.00
6	Reinforcement bars	4,458,380.00
7	Separation membrane	480,855.40
8	Subtotal	62,353,455.40
9	Contingency allowance	6,235,245.54
10	Total Cost per km	68,587,700.94

Table 4.1b: Summary of Bill of Engineering Measurement and Evaluation (BEME) for initial construction cost of asphalt pavement at Isieke Ebonyi State (Adjusted from proposed Ebonyi State Ministry of Works, BEME 2010).

Item No	Description	Unit	Qty	Rate	Amount
Bill No 1: Pavement and Sub-grade work.					
1.01	Compact earthen sub-grade material to the required level using vibratory rollers	m ²	9,800.00	300.00	2,940,000.00
	Total bill no 1: carried to summary				2,940,000.00
Bill No 2: Pavement and Sub-base work.					
2.01	Import and compact fill material at sub-base level to required depth	m ²	10,400.00	300.00	3,120,000.00
	Total bill no 2: carried to summary				3,120,000.00
Bill No 3: Pavement and Road base work.					
3.01	Import and compact granular material at base course level to required depth	m ²	13,200	350.00	4,620,000.00
	Total bill no 3: carried to summary				4,620,000.00

Bill No 4: Pavement and Surfacing					
4.01	Provide and apply bituminous emulsion tack coat on the entire carriageway.	m ²	12,500.00	300.00	3,750,000.00
4.02	Provide and lay 100mm compacted thickness of hot rolled asphalt (HRA) wearing course constituting of 12% bitumen content.	m ²	12,800.00	2,600.00	33,280,000.00
	Total Bill No 4: carried to summary.				37,030,000.00
	General Summary				
	Bill No 1: Pavement and Sub-grade work				2,940,000.00
	Bill No 2: Pavement and Sub-base work.				3,120,000.00
	Bill No 3: Pavement and Road-base work				4,620,000.00
	Bill No 4: Pavement and Surfacing				37,030,000.00
	Subtotal				47,710,000.00
	Contingency allowance				4,771,000.00

	Total cost per km				52,481,000.00
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Table 4.2a Agency (Authority) Cost of Concrete Pavement (Computed from Ebonyi State Ministry of Works Data).

S/NO	Activity	Cost (Naira)	Remark
1	Construction Cost	68,587,700.94	-----
2	Routine Maintenance Cost	2,346,740.00	Every ten years interval
3	Periodic Maintenance Cost	845,750.75	Every fourteen years interval
4	Rehabilitation Cost	950,780.50	After forty years
5	Salvage Cost	475,390.25	-----

Table 4.2b Agency (Authority) Cost of Flexible Pavement (Computed from Ebonyi State Ministry of Works Data).

S/NO	Activity	Cost (Naira)	Remark
1	Construction Cost	52,481,000.00	-----
2	Routine Maintenance Cost	5,608,350.00	Twice every five years
3	Periodic Maintenance Cost	2,378,000.00	Once every eight years
4	Rehabilitation Cost	3,330,304.97	At every ten years interval.
5	Salvage Cost	1,665,152.485	-----

Table 4.3 Life Cycle Cost of Concrete and Asphalt Pavement

Description	Concrete (Naira)	Asphalt (Naira)	Difference
Initial Construction Cost	68,587,700.94	52,481,000.00	16,106,700.94
Routine Maintenance Cost	3,060,148.96	29,253,153.6	26,193,004.64
Periodic Maintenance Cost	827,144.23	3,876,140.00	3,048,995.77
Rehabilitation Cost	309,954.443	4,342,717.68	4,032,763.237
Salvage Value	-154,977.22	-542,839.71	387,862.49
Fuel Cost	132,214,779.00	131,849,105.7	365,673.3
Time Saving Cost	-1,494,675.00	-597,870.00	896,805.00
Total Cost in 40 years	203,350,075.353	220,661,407.27	17,311,331.917

4.2 ANALYSIS OF RESULTS

4.2.1 Construction Cost

The data sourced on the initial construction cost of Concrete and flexible pavement, indicate that after thorough adjustment using the current inflationary rate, the Concrete pavement was relatively higher than the flexible pavement with a cost difference of about 16.1 million. This can be attributed to the cost of materials that constitute a Concrete pavement and also from this result, it can be deduced that there is a relative economy in the construction cost of flexible pavement than that of Concrete pavement. This result mirrors the work of Yonas et al, (2016).

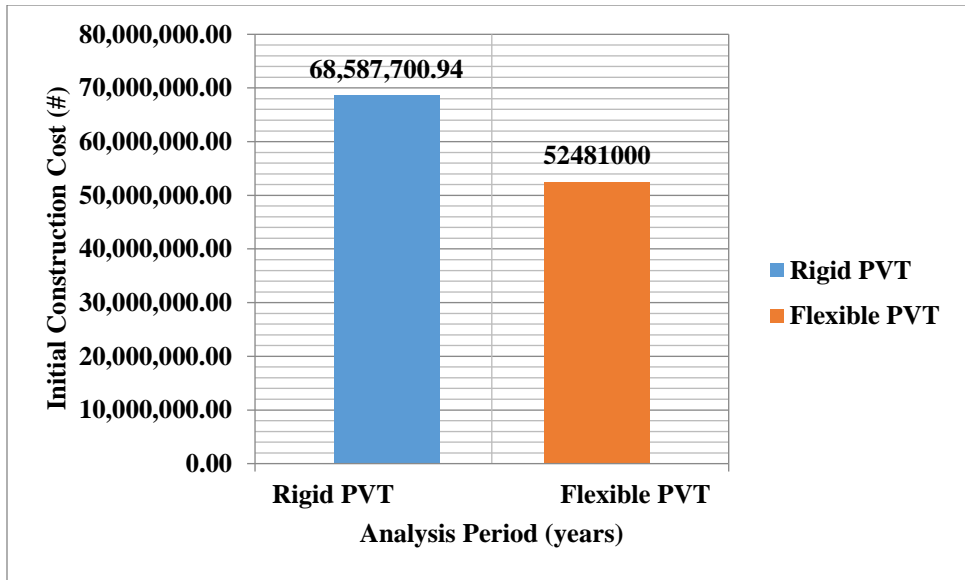
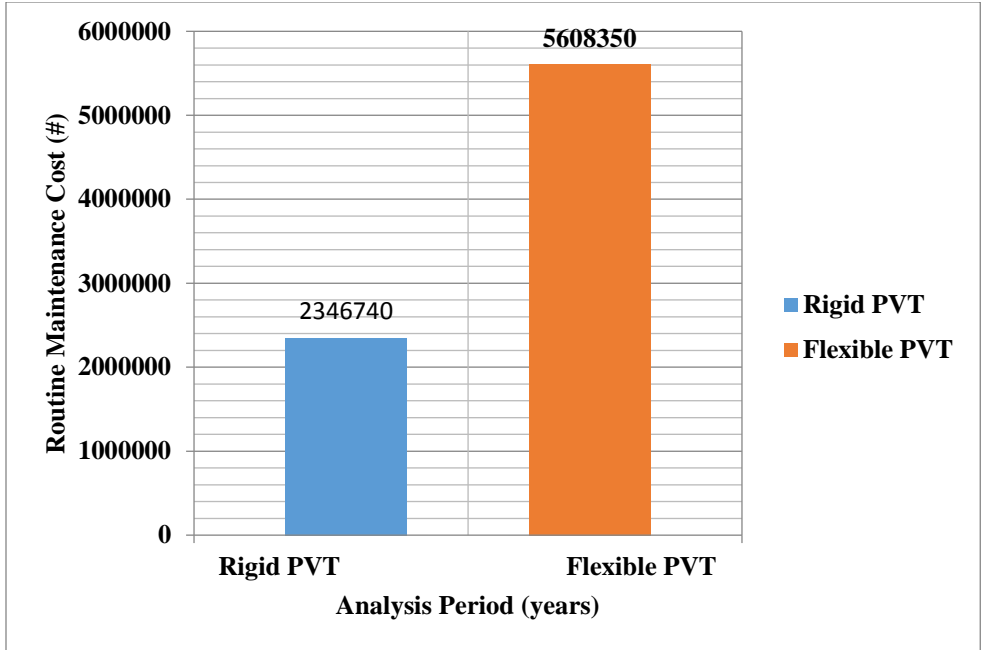


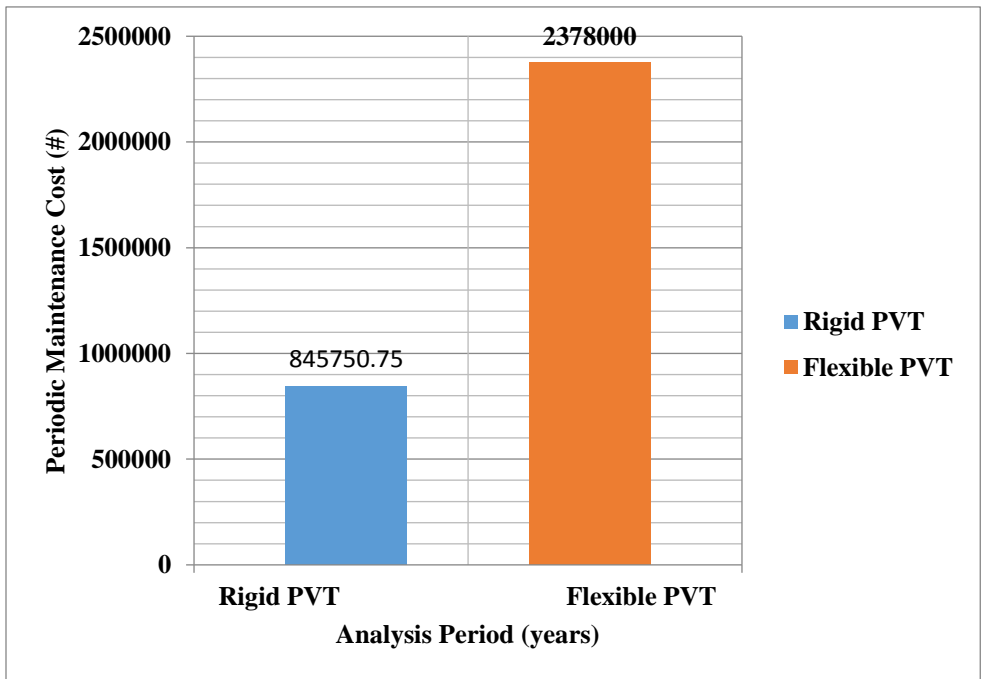
Fig 4.0: Chart showing the initial construction cost of both pavement against Analysis Period.

4.2.2 Maintenance Cost

The life time maintenance of both Concrete and flexible pavement was categorized into periodic and routine maintenance schedule. The periodic and routine maintenance of Concrete pavement was conducted at every 14 and 10 years interval while that of the flexible pavement was carried out every eight and five years respectively. This maintenance was conducted before and after the period of high rainfall intensity. Result obtained from the maintenance cost suggests that the periodic and routine maintenance cost of flexible pavement was considerably higher than that of Concrete pavement. This is mainly due to the frequency at which this maintenance was conducted as flexible pavement are susceptible to distress even at the early stage of it service life. This result is in agreement with the works of Yonas et al, (2016) and Audu et al, (2015).



4.1a: Chart showing the routine maintenance cost of both pavements against analysis period.



4.1b: Chart showing the periodic maintenance cost of both pavements against analysis period.

4.2.3 Rehabilitation Cost

The rehabilitation cost is the cost of full depth repair in Concrete pavement or removal and replacement of asphalt (resurfacing) in asphalt pavement. According to the rehabilitation activities schedule specified in the work, the Concrete pavement will be rehabilitated at the end of the analysis period (40 years) while the flexible pavement will be rehabilitated at every ten years intervals. Comparative deduction extracted from the rehabilitation cost of the competing alternatives suggests that the rehabilitation cost of flexible pavement was appreciably higher than that of Concrete pavement with a substantial discrepancy in cost. This development can be attributed to the higher frequency in rehabilitation exercise for flexible pavement which cumulatively amount to cost. Studies indicative of the results are the works of Yonas et al, (2016) and Audu et al, (2015).

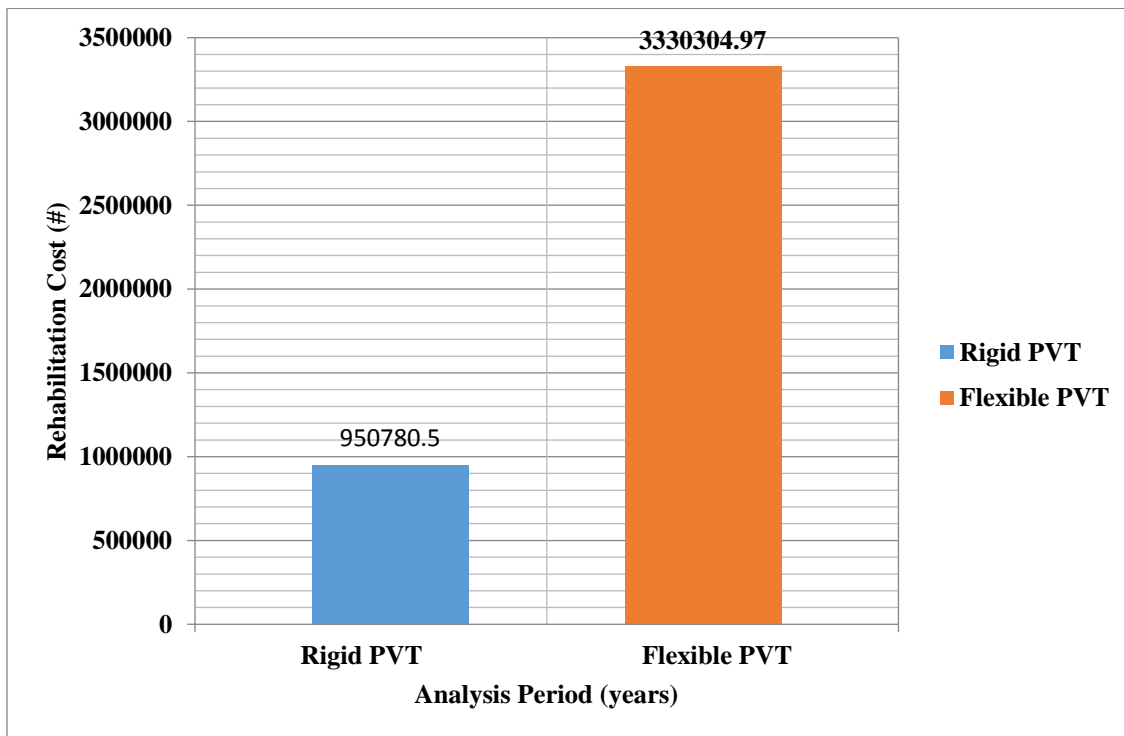


Fig 4.2: Chart showing the rehabilitation cost of both pavements against analysis period.

4.2.4 Salvage Cost

Salvage cost is the cost recovered from expenses incurred due to the rehabilitation of the competing alternatives. It is expressed mathematically as rehabilitation cost multiplied by expected remaining life of the rehabilitation cost divided by total expected life of the rehabilitation cost. This cost is deducted from the total cost incurred due to the agency and user cost of both pavements. Result obtained indicates that the salvage cost of asphalt pavement was appreciably higher than that of Concrete pavement implying higher recovery from rehabilitation cost.

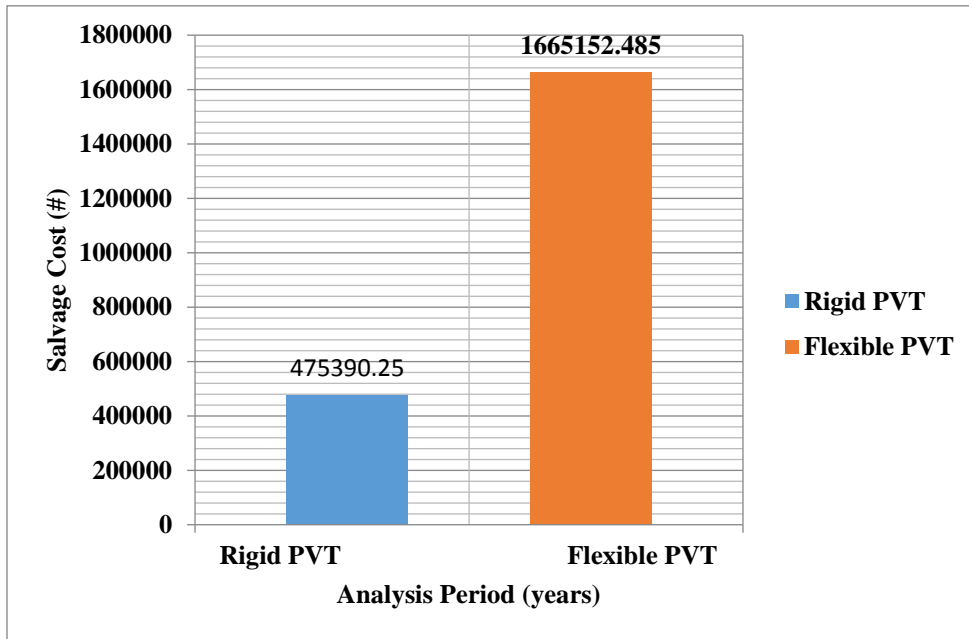


Fig 4.3: Chart showing the salvage cost of both pavements against analysis period.

4.2.5 User Cost.

The user cost comprises of both vehicle time saving and delay cost and also fuel cost for the two pavement options. The user cost was computed from the annual average daily traffic data collected from ministry of works Ebonyi state. Results obtained indicate that the time saving and delay cost of Concrete pavement were comparatively higher than that of flexible pavement while the fuel cost of flexible pavement is higher than that of Concrete pavement. This result implies that there is higher energy consumption (fuel usage) and less delay cost in flexible pavement than that of Concrete pavement.

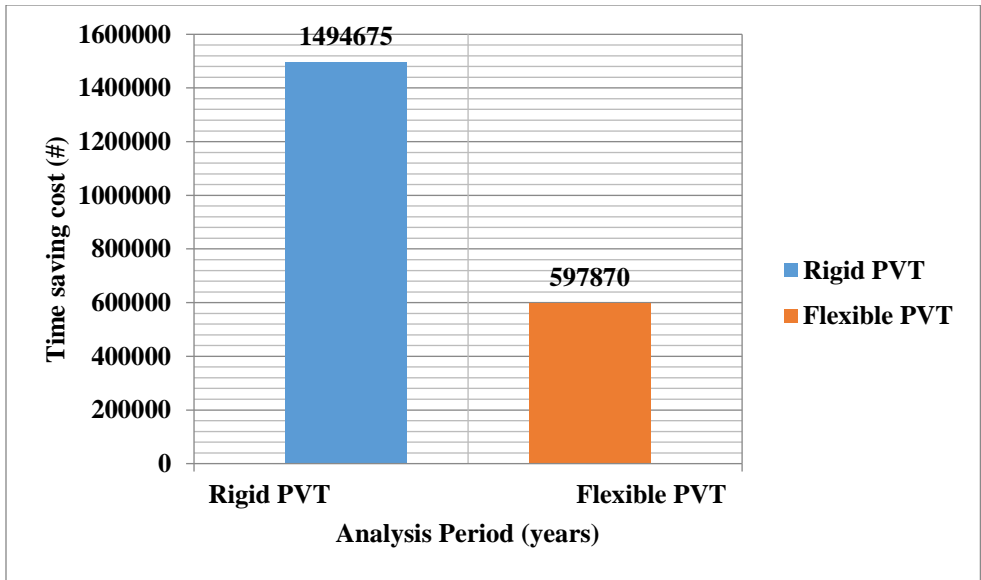


Fig 4.4a: Chart showing the time saving cost of both pavements against analysis period.

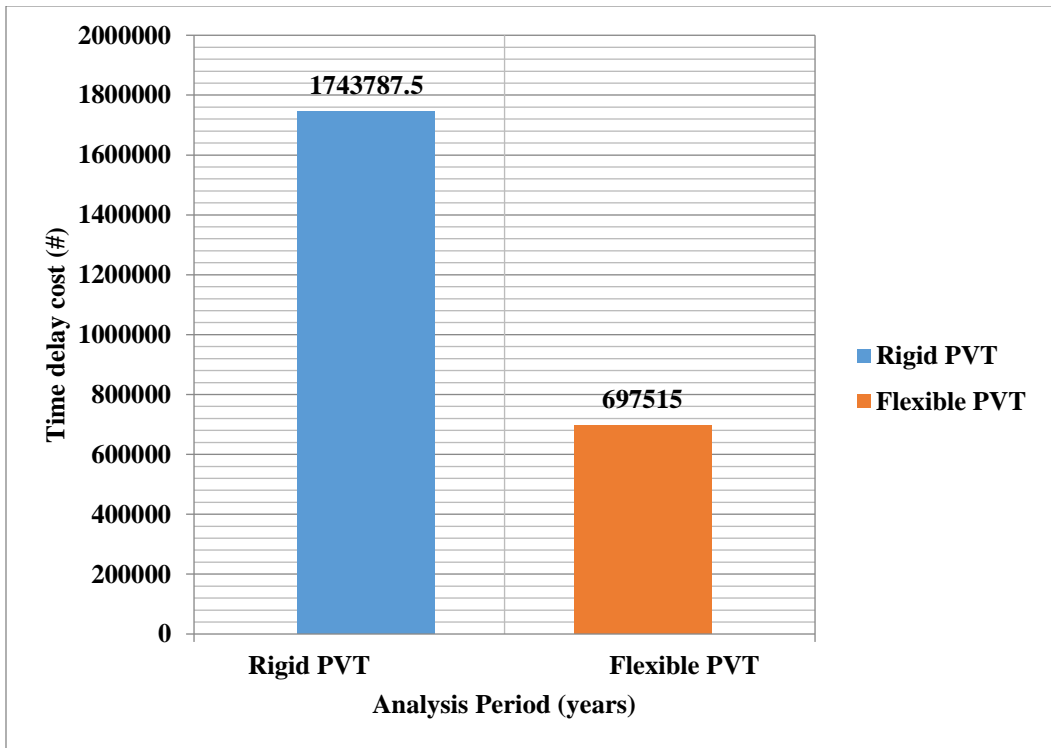


Fig 4.4b: Chart showing the time delay cost of both pavements against analysis period.

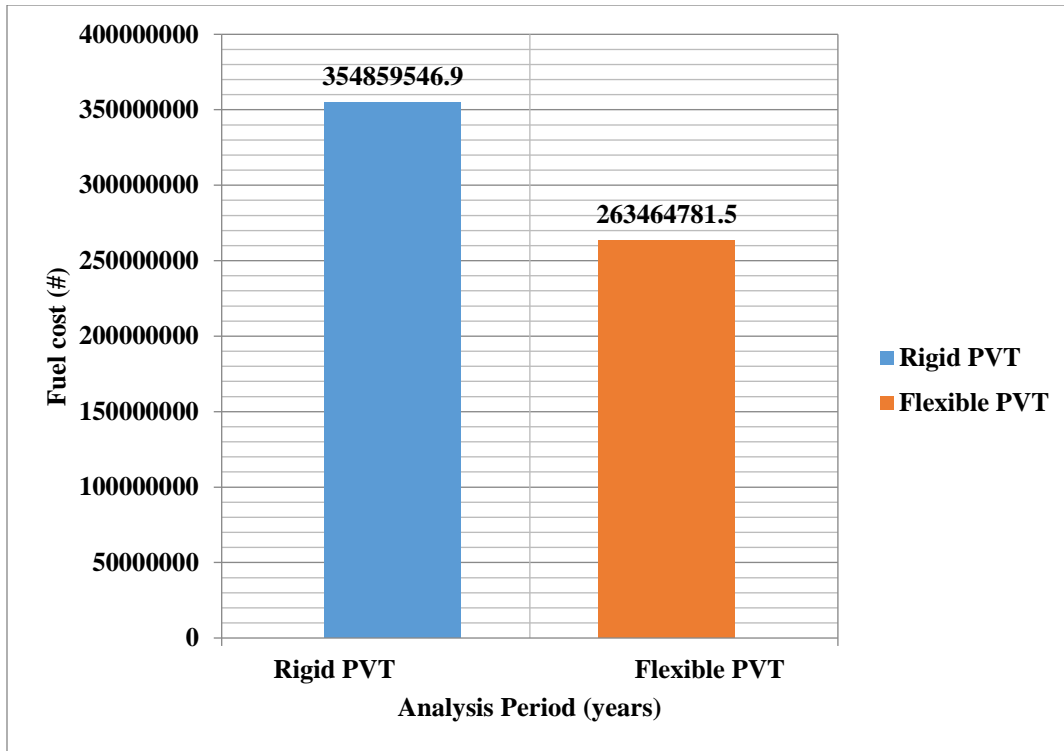


Fig 4.4b: Chart showing the fuel cost of both pavements against analysis period.

4.2.6 Life Cycle Cost.

The comparison of the economic worth of the competing alternatives was done from the findings obtained from the life cycle cost of both pavement types with an analysis period of 40 years. This result is employed as a supporting tool for investment decision on economic viable alternatives. Result obtained from the life cycle cost of both alternatives indicate that the Concrete pavement has longer service life than flexible pavement and for 1km (kilometer) road length, the life cycle cost of the Concrete pavement is lower by a value of 17.3 million in Naira than that of the asphalt pavement in forty (40) years analysis period. This result suggests that the Concrete pavement is an economically viable alternative than the asphalt pavement due to it lower life cycle cost and longer service life. Life cycle cost comparison in currency suggest that 1km (kilometer) road length in USD (United State Dollar) for both asphalt and Concrete pavement requires 537267 and 495129 USD respectively, this result is in correlation with the works of Yonas et al, (2016) and Audu et al, (2015).

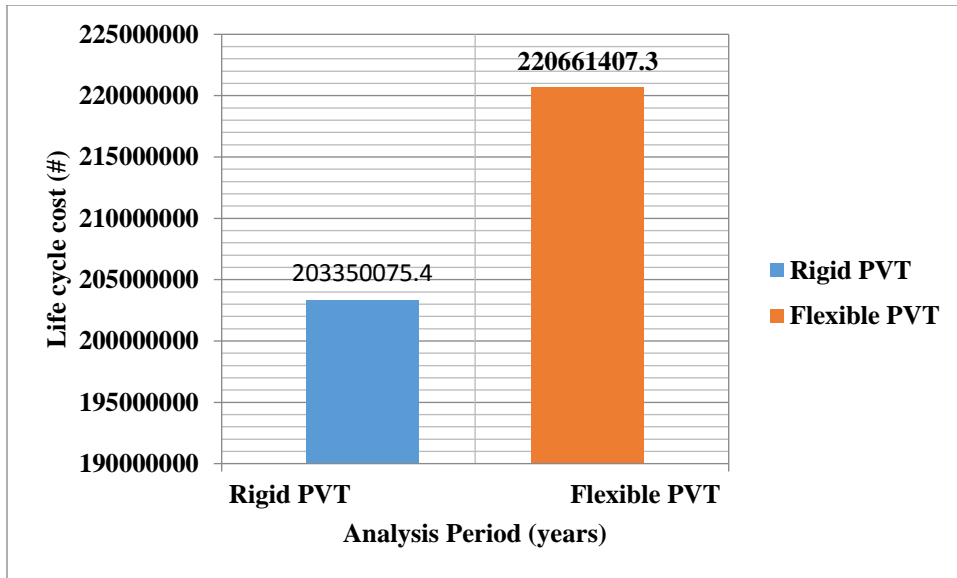


Fig 4.5a: Chart showing the life cycle cost of both pavements against analysis period in Naira.

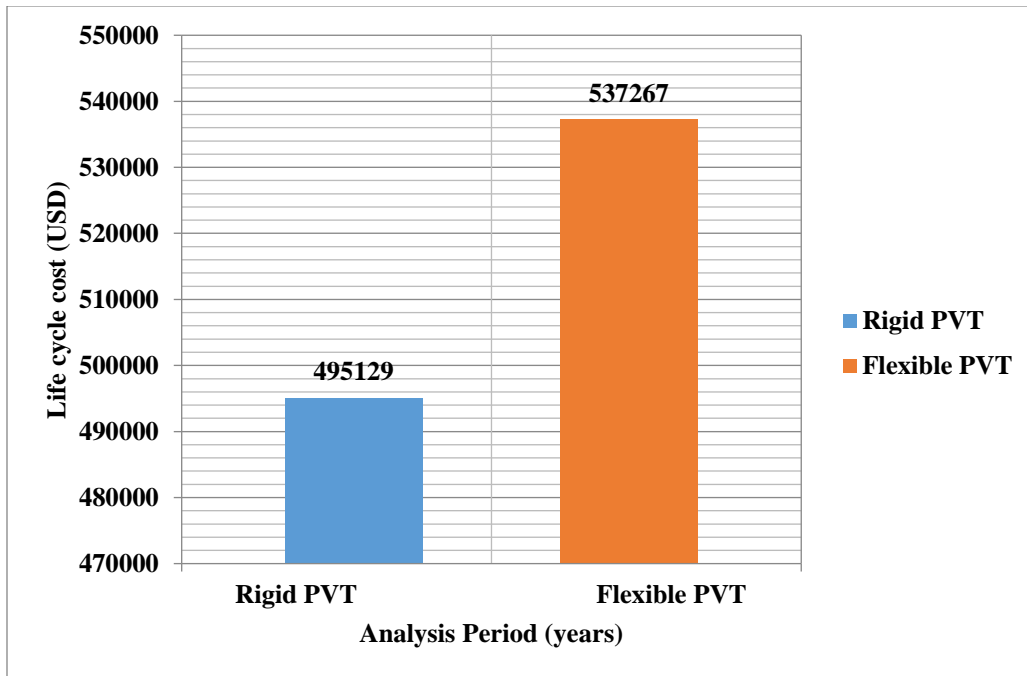


Fig 4.5b: Chart showing the life cycle cost of both pavements against analysis period in USD.

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATION

5.1 CONCLUSION

From the findings obtained the following conclusion was made:

1. The data sourced on the initial construction cost of Concrete and asphalt pavement, indicate that after thorough adjustment using the current inflationary rate, the Concrete pavement was relatively higher than the flexible pavement with a cost difference of about 16.1 million.
2. This maintenance conducted before and after the period of high rainfall intensity suggests that the periodic and routine maintenance cost of asphalt pavement was considerably higher than that of Concrete pavement. This is mainly due to the frequency at which this maintenance was conducted as asphalt pavement are susceptible to distress even at the early stage of its service life.
3. Comparative deduction extracted from the rehabilitation cost of the competing alternatives suggests that the rehabilitation cost of flexible pavement was appreciably higher than that of Concrete pavement with a substantial discrepancy in cost.
4. The salvage cost derived from the rehabilitation cost indicates that the salvage cost of asphalt pavement was appreciably higher than that of Concrete pavement implying higher recovery from rehabilitation cost.
5. Results obtained from the user cost indicate that the time saving and delay cost of Concrete pavement were comparatively higher than that of asphalt pavement while the fuel cost of asphalt pavement is higher than that of Concrete pavement.
6. Result obtained from the life cycle cost of both alternatives indicate that the Concrete pavement has longer service life than asphalt pavement and for 1km (kilometer) road length, the life cycle cost of the Concrete pavement is lower by a value of 17.3 million in Naira than that of the asphalt pavement in forty (40) years analysis period.
7. The 1km (kilometer) Concrete pavement is therefore adjudged as an economically viable alternative over asphalt pavement due to its relatively lower life cycle cost and higher service life and as a result must be given due consideration by prospective investors.

5.2 RECOMMENDATION

The following recommendation can be made from the research findings obtained:

1. Concrete pavement is adjudged as an economically feasible alternative over asphalt pavement due to its relatively lower life cycle cost and higher service life.
2. For widespread construction of Concrete pavement over asphalt pavement, this study recommends that consulting and contracting firms must convince their client over the economic and life cycle benefit of Concrete pavement over flexible pavement.
3. Academic institutions must promote the economic and life cycle benefit of Concrete pavement over asphalt pavement through robust tutelage and professional bodies (NSE) must raise awareness on the necessity of Concrete pavement over asphalt pavement.

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APPENDICES

APPENDIX A

CONSTRUCTION COST

Table A1 Summary of Initial Construction Cost of 1km Concrete Pavement at Isieke Ebonyi State (Sourced and adjusted from Ministry of Works Ebonyi State).

Item No	Description	Total Cost (Naira)
1	Sub-grade level	3,240,000.00
2	Sub-base level	4,724,000.00
3	Concrete Pavement	48,728,000.00
4	Texturing and Curing	640,740.00
5	Joints	80,480.00
6	Reinforcement bars	4,458,380.00
7	Separation membrane	480,855.40
8	Subtotal	62,353,455.40
9	Contingency allowance	6,235,245.54
10	Total Cost per km	68,587,700.94

Table A2: Summary of Bill of Engineering Measurement and Evaluation (BEME) for initial construction cost of flexible pavement at Isieke Ebonyi State (Adjusted from proposed Ebonyi State Ministry of Works, BEME 2010).

Item No	Description	Unit	Qty	Rate	Amount
Bill No 1: Pavement and Sub-grade work.					
1.01	Compact earthen sub-grade material to the required level using vibratory rollers	m ²	9,800.00	300.00	2,940,000.00
	Total bill no 1: carried to summary				2,940,000.00
Bill No 2: Pavement and Sub-base work.					
2.01	Import and compact fill material at sub-base level to required depth	m ²	10,400.00	300.00	3,120,000.00
	Total bill no 2: carried to summary				3,120,000.00
Bill No 3: Pavement and Road base work.					
3.01	Import and compact granular material at base course level to required depth	m ²	13,200	350.00	4,620,000.00
	Total bill no 3: carried to summary				4,620,000.00

Bill No 4: Pavement and Surfacing					
4.01	Provide and apply bituminous emulsion tack coat on the entire carriageway.	m ²	12,500.00	300.00	3,750,000.00
4.02	Provide and lay 100mm compacted thickness of hot rolled asphalt (HRA) wearing course constituting of 12% bitumen content.	m ²	12,800.00	2,600.00	33,280,000.00
	Total Bill No 4: carried to summary.				37,030,000.00
	General Summary				
	Bill No 1: Pavement and Sub-grade work				2,940,000.00
	Bill No 2: Pavement and Sub-base work.				3,120,000.00
	Bill No 3: Pavement and Road-base work				4,620,000.00
	Bill No 4: Pavement and Surfacing				37,030,000.00

	Subtotal				47,710,000.00
	Contingency allowance				4,771,000.00
	Total cost per km				52,481,000.00

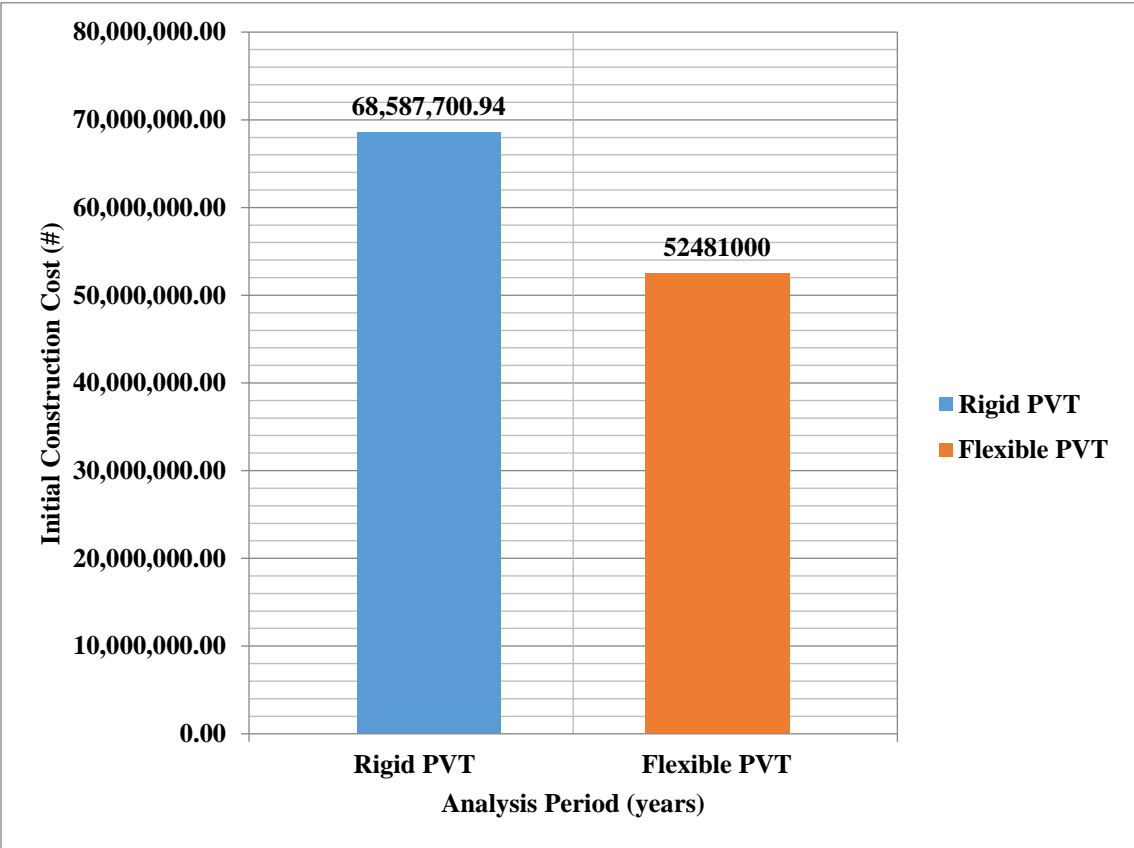


Fig A1: Chart showing the construction cost of both pavements against analysis period.

APPENDIX B

MAINTENANCE AND REHABILITATION COST

Table B1 Flexible Pavement Routine Maintenance Schedule (Sourced and adjusted from Ministry of Works Ebonyi State).

Frequency in a year	Month of a year	Routine Maintenance Activities	Cost (Naira)	Remark
1st	March	Potholes and chip seals	2,484,350.00	Twice (2) a year before and after the rainy season.
	April			
	May			
2nd	October	Potholes Patching	3,124,000.00	
	November			
	December			
			5,608,350	

Table B2 Flexible Pavement Periodic Maintenance Schedule (Sourced and adjusted from Ministry of Works Ebonyi State).

Frequency in a year	Month of a year	Periodic Maintenance Activities	Cost (Naira)	Remark
1 st	March	Pothole repair and repainting of white line.	2,378,000.00	Once every year before and after the rainy season.
	April			
	May			
			2,378,000.00	

Table B3 Schedule of Maintenance and Rehabilitation Cost of 1km Concrete Pavement (Sourced and Modified from Ministry of Works Ebonyi State.)

Maintenance Type	Activity	Cost (Naira)	Frequency in years
Routine Maintenance	Joint sealing and crack sealing	2,346,740.00	Every 10 years interval
Periodic Maintenance	Partial depth repair	845,750.75	Every 14 years interval
Rehabilitation	Full depth repair	950,780.50	At 40 years

APPENDIX C

AGENCY AND USER COST

Table C1 Agency (Authority) Cost of Concrete Pavement (Computed from Ebonyi State Ministry of Works data).

S/NO	Activity	Cost (Naira)	Remark
1	Construction Cost	68,587,700.94	-----
2	Routine Maintenance Cost	2,346,740.00	Every ten years interval
3	Periodic Maintenance Cost	845,750.75	Every fourteen years interval
4	Rehabilitation Cost	950,780.50	After forty years
5	Salvage Cost	475,390.25	-----

Table C2 Data of Vehicle Time Saving Cost Computation for both Pavement (Data Sourced from Ministry of Works Ebonyi State).

Vehicle Type	AADT (2021-2035)	Composition (%)	No of Vehicles	Time Saving/day/km	Time Saving/day
Small bus	454	42	191	0.3	57.3
Medium bus	454	4	18	0.3	5.4
Large bus	454	3	14	0.3	4.2
Medium Truck	454	26	118	0.3	35.4
Heavy Truck	454	13	59	0.3	17.7
Truck Trailer	454	12	55	0.3	16.5
Total	454	100	455	18	136.5

Table C3 Agency (Authority) Cost of Flexible Pavement (Computed from Ebonyi State Ministry of Works data).

S/NO	Activity	Cost (Naira)	Remark
1	Construction Cost	52,481,000.00	
2	Routine Maintenance Cost	5,608,350.00	Twice every five years
3	Periodic Maintenance Cost	2,378,000.00	Once every eight years
4	Rehabilitation Cost	3,330,304.97	At every ten years interval.
5	Salvage Cost	1,665,152.485	

APPENDIX D

LIFE CYCLE COST

Table D1 Life Cycle Cost of 1km Concrete and Flexible Pavement.

Description	Concrete (Naira)	Flexible (Naira)	Difference
Initial Construction Cost	68,587,700.94	52,481,000.00	16,106,700.94
Routine Maintenance Cost	3,060,148.96	29,253,153.6	26,193,004.64
Periodic Maintenance Cost	827,144.23	3,876,140.00	3,048,995.77
Rehabilitation Cost	309,954.443	4,342,717.68	4,032,763.237
Salvage Value	-154,977.22	-542,839.71	387,862.49
Fuel Cost	132,214,779.00	131,849,105.7	365,673.3
Time Saving Cost	-1,494,675.00	-597,870.00	896,805.00
Total Cost in 40 years	203,350,075.353	220,661,407.27	17,311,331.917

