An Exploration of the Feasibility of Using Plastic Waste for Sustainable Road Construction in Nigeria: A Qualitative Approach

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Abstract
Every country, both developed and developing, has problems with waste management, specifically plastic waste. Plastic wastes are non-biodegradable and can decompose between 100 to 500 years. The negative impact of plastic waste is felt by the environment and all forms of living things, either on the land, in the air, or underwater, because of the chemical composition of plastic and its poor management. Nigeria, as a developing country, is faced with a poor and inadequate road network with about 200,000km road network and only 50,000km paved; therefore, there is a need to make more roads that are environmentally friendly, socially comfortable and accessible, and economically feasible. Thus, this research identifies and evaluates the factors that could promote or hinder the adoption of plastic waste for road construction. Highway construction professionals in Nigeria were interviewed and the data analysed thematically. The findings showed that awareness, government policy, funding, technical know-how, political will, equipment, standardised methodology, practical-knowledge gap and a sample trial hinder the adoption of plastic waste for road construction in Nigeria. However, the enables include global warning concerns, government policies and environmental awareness. Based on this research, it is evident that raising awareness and training amongst stakeholders, the balance between hands-on and classroom training, pilot construction, funding, and government policy is important for adopting plastic waste for road construction.

Keywords
Sustainable Road Construction, Plastic Waste, Nigeria

1 Introduction

Plastic waste pollution is an escalating global environmental crisis. Since the 1950s, approximately 7.8 billion tons of plastic have been produced worldwide, with only 9% recycled and 12% incinerated (Dibia *et al.* 2023). This has led to significant environmental harm, which endangers both the environment and its population (Ogundana 2023). About 12.7 million tons of plastic waste are found

in the ocean (Canado *et al.* 2022) due to poor management (Boucher and Friot 2017). In Nigeria, road transportation is a crucial driver of socio-economic development (Tiza *et al.* 2022; Mohammed 2023). However, road infrastructure primarily depends on non-renewable materials such as bitumen and cement, lime, and natural aggregates which contributes to unsustainable resource consumption and environmental degradation (Bamigboye *et al.* 2021). With rapid urbanisation and population growth (Wang *et al.* 2023), there is an urgent need for alternative, eco-friendly materials for road construction—such as plastic waste—rather than allowing it to damage the environment further.
According to the European Commission (2015), to move in the direction of a circular economy, there should be the reintroduction of plastic waste into production processes as either materials or energy, which can be achieved through methods such as recycling, composting, or waste-to-energy incineration (Chen *et al.* (2020). In plastic waste recycling, plastic waste materials are managed and reused (Kalali *et al.* 2023). This involves collecting and sorting plastic waste, converting it into raw materials, and using it to produce new products. For a road transport infrastructure to be sustainable, the needs of the current road users must be met without compromising future development (Adepoju 2021). Therefore, using waste materials for construction projects, particularly in building roads, shows potential for more environmentally friendly and sustainable practices (Almokdad and Zentar 2023).

Previous studies on using plastic waste for road construction, for example Dawodu *et al.* 2023 and Ahmed 2023, had adopted a quantitative approach on primary and secondary data sources. Using qualitative approach to gain a deep understanding of this in the country rare. Further, why this sustainable method of constructing roads has not been implemented widely has received little attention. In support, extant studies such as Das and Das (2023) report practical knowledge gap in that using plastic waste in road construction is not widely practised, both nationally and globally, despite numerous research. The present study used a qualitative method to investigate the adoption and usage of plastic waste for road construction. Therefore, using the qualitative approach, the current study identifies the potential barriers and enablers for the adoption of plastic waste for road construction in Nigeria. Nigerian road infrastructure deficit is about 70%, and out of its 200,000km road network, only 50,000km is paved (Sami 2022).

2 Literature Review

2.1 Global Initiatives and Success Stories in Using Plastic Waste for Road Construction

Plastic waste for road construction has been used by a countries such as India, the UK, Ghana, the Netherlands, Ethiopia (Sasidharan *et al.* 2019), USA, Abu Dhabi, Australia, Saudi Arabia, Bahrain, and Canada (Smith 2018). Plastic waste can be used in place of the various components typically used in cementitious composites, such as binder, fibre, and aggregate (Kalali *et al.* 2023). There are two methods of construction using plastic waste, which are dry and wet processes (Sasidharan *et al.* 2019). There are several initiatives on road construction using plastic waste from different countries. For instance, new policies and procedures were put in place in Hamburg, Germany stating that the roads must be constructed using only recycled materials (Schroeder 2015). Also in India, there was an initiative in 2013 whereby all states requesting the Pradhan Mantri Gram Sadhak Yojana (PMGSY) funding were mandated to use innovative approaches like the use of industrial waste, and green technology for the construction of at least 15% of the rural roads, this is to "(i) conserve nonrenewable natural resources by using alternative, environmentally-friendly materials; (ii) utilize waste materials in rural road construction" and (iii) reduce construction costs (Heriawan 2020).
In 2002, India constructed the first plastic road. Working with academics from Bangalore University, Ahmed and Khan, a plastic waste management company in Bangalore (KK Plastic Waste Management), laid more than 3000km of plastic roads using 15,000tonnes of plastic waste in

Bangalore (Smith 2018). These roads are still in good shape without rutting, ravelling, or potholes after about 10 years of construction (Indian Road Congress 2013; Vasudevan *et al.* 2012).
In the UK, MacRebur, a Scottish company owned by Toby McCartney has used waste plastic mixed with asphalt for the surfacing and construction of roads (White and Reid 2018). Equally, MacRebur constructed the first road made with plastic binder instead of the traditional bitumen binder in the United States at the University of California (Xu *et al.* 2021). In the g**,** PlasticRoad is a private organization that created its first trial of a road without concrete and asphalt in 2016 and reported that for over a year, cars and trucks of small sizes rode on it daily without problem (Barnett 2021).

2.1.1 The Case of Nigeria

The majority of Nigerian paved roads are asphalt roads, such as Abuja-Kaduna, Portharcourt-Enugu, Lagos-Ibadan, and Lokoja-Abuja expressways, and a few concrete roads, like the Oshodi-Apapa road and the Kaba-Obajana road in Lagos and Kogi State, respectively (Mohammed, 2023). There is potential for the use of plastic in Nigeria. However, studies have not investigated it. Therefore, Nigeria was chosen as a unit of study to investigate the barriers and enablers in the adoption of plastic waste for road construction in Nigeria.

3 Research Methodology

To better understand the obstacles and enablers of the adoption of plastic waste for road construction in Nigeria, the research onion model and paradigm by Saunders et al. (2009) was used. This study embraced an interpretivism research philosophy and inductive approach, using a semi-structured interview with highway construction professionals in Nigeria to achieve the research objectives.

3.1 Data Collection

Literature to understand the argument surrounding the topic. Some secondary data were obtained from available literature reviews on the Web of Science, Scopus, the University of Wolverhampton Library, and Google Scholar to gather current knowledge and understanding of the enablers and barriers of adopting waste plastic for the construction of roads. Primary data were subsequently collected across Nigeria and analysed. Purposive sampling was adopted to choose interviewees based on their career background and acquired skills to answer the research questions (Daniel and Pasquire 2019). This research recruited professional participants (engineers, government agency directors, land and quantity surveyors, site directors, architects and other vital stakeholders) who were connected through senior colleagues, and professional sites like LinkedIn. Participants with at least 8 to 30 years of experience were drawn purposively from the road/highway construction industry with professional membership such as Quantity Surveyors Registration Board of Nigeria, Nigerian Society of Engineers, Federal Road Maintenance Agency, Federation of Construction Industry, Nigerian Building and Road Research Institute, Nigerian Institute of Quantity Surveyors. They were recruited from across the six Geopolitical zones in Nigeria to give the study better coverage.
The research instrument used was a semi-structured interview, which had prompts to guide the researcher and ensure necessary questions were asked to explore the participant's experience on the enablers and barriers of adopting waste plastic for the construction of roads in Nigeria. The semi-structured interview allows participants the ability to express their views and experiences freely (Bryman, 2016), and it is open-ended; this is because participants tend to feel more at ease responding to them (Aberbach and Rockman 2002); also, identified participants can ask questions if needed (Daniel *et al.* 2023).
A consent form was sent to all the identified participants to read, provide their email addresses, and sign. The form gave them an insight into the research aim and objectives as well as their freedom to

withdraw at any time without giving reasons. The research was also approved by the University ethics committee before the data collection. The selected participants were interviewed on Microsoft Teams, WhatsApp, Google Meet, and Zoom. The responses gathered were recorded and transcribed verbatim to avoid missing out on any data (Harvey 2021). The interviews continued until saturation was reached, and there were 23 interviews. Data collection saturation is the extent to which new data is the same as previous data (Saunders et al. 2017); this was used as a guide for this research. Table 1 shows the research participants demographically.

Table 1: Participant Information

Participant Job Title	Participant Sector	Years of Experience	Professional Bodies Affiliation	Geopolitical Location	Theme Code
Design Infrastructure Engineer	Private	12	COREN and NSE	Lagos	CE001
Project Engineer	Private	9	COREN and NSE	Adamawa	CE002
Environmentalist	Public	15	COREN and NSE	Oyo	EN003
Civil Engineer	Public	23	COREN	Abuja	CE004
Civil Engineer	Private	30	COREN and NSE	Lagos	CE005
Design Infrastructure Engineer	Private	14	COREN and NSE	Rivers	CE006
Highway Engineer	Private	12	COREN and NSE	Cross River	CE007
Civil and Building Engineer	Private	18	NICE, GBCN and NSE	Abuja	CBE008
Assistant Chief Engineer	Public	18	COREN and NSE	Abuja	CE009
Civil Engineer	Public	9	COREN and NSE	Enugu	CE010
Project Engineer	Private	16	COREN and NSE	Oyo	CE011
Highway Engineer	Private	12	COREN and NSE	Lagos	CE012
Civil Engineer	Public	12	COREN and NSE	Ondo	CE013
Transportation Engineer	Private	11	COREN and NSE	Ondo	TE014
Civil Engineer	Public	8	COREN and NSE	Oyo	CE015
Engineering Surveyor	Private	9	SURCON	Kaduna	ES016
Civil Engineer	Private	15	COREN	Abuja	CE017
Civil Engineer	Public	10	COREN and NSE	Delta	CE018
Highway Engineer	Public	12	COREN	Lagos	CE019
Civil Engineer	Private	12	COREN and NSE	Cross River	CE020
Project Engineer	Private	13	COREN and NSE	Abia	CE021
Civil Engineer	Public	8	COREN and NSE	Ogun	CE022
Civil Engineer	Private	10	COREN	Anambra	CE023

3.2 Data Analysis

Each of the recordings was given a unique code for ease of identification. The data were analysed using thematic analysis by i) familiarizing with the data, ii) creating codes, iii) searching the transcript for themes, iv) reviewing the themes, v) defining the themes and naming them and vi) finally producing a report which are the six steps defined by Braun and Clarke (2006). Section 4 shows the presentation and discussion outcome of the themes derived from the data.

4 Results and Discussion

4.1 Potential Enablers for the Adoption of Plastic Waste for Road Construction.

The emerging themes are presented in figure 1. According to the participants, the following themes were extracted from their responses on potential enablers for the adoption of plastic waste for road construction; global warming concern, pilot sample/develop a standard, readily available material,

training, orientation/awareness, international investors, research and development, reward for disposal, government policy. The study found that the research community needs to do more by publishing in journals and conferences about this discussion for it to be adopted. Further, there should be public awareness and education to educate the public about this innovative method, especially stakeholders. however, only a few of the participants' said people are becoming aware of global warming; therefore, this would encourage them to adopt this method. Furthermore, some participants said there should be adequate training provided to professionals about its application to help spread the knowledge for easy implementation.

Figure 1: Enablers for adopting plastic waste in road construction

For instance,

> *"Then of course the research community, we need to do more research, we need to collaborate with institutions both within and outside the country to do research into some of these products and publish in journals and conferences to show that this is doable." (CBE008)*
>
> *"Passing the message across to various stakeholders like in Nigeria, there are seminars organized by Nigerian Society of Engineers where most of the stakeholders actually come together. There are seminars organized, sometimes even by the Council, for regulation of engineering practicing." (CE005)*
>
> *"If we want to promote it, I think to promote anything is, uh, public education is very important, so if the people are not even aware the people in the government, Federal Ministry of Works, uh State Ministry of Works Rd., housing, whatever. (EN003)*

This view resonates with the findings of Poulikakos *et al.* (2017), who reported that for road construction using waste, appropriate standards and laws should be made available to professionals as a guide, and the knowledge acquired by the research community should be brought to the practising professionals; all these are achievable by involving the stakeholders. According to some participants, engaging policy makers and stakeholders would increase the possibility of the government adopting this innovative method thereby enforcing the policy.

For instance,*"If stakeholders at the top accept and insist ok oh, contractor we want to give you road construction to do but if you must do this road, we want you to use plastic pavement." (CE006)*

This view aligns with the finding in Hamburg, Germany, where new policies and procedures were put in place stating that roads must be constructed using only recycled materials (Schroeder, 2015). Furthermore, in India, there was an initiative in 2013 whereby all states requesting for the Pradhan Mantri Gram Sadhak Yojana (PMGSY) funding were mandated to use innovative approaches like the use of industrial waste, and green technology for the construction of at least 15% of the rural roads, this is to "(i) conserve nonrenewable natural resources by using alternative, environmentally-friendly

materials; (ii) utilize waste materials in rural road construction" and (iii) reduce construction costs (Heriawan, 2020). Additionally, few participants said plastic waste, being the raw material, is readily available and inexpensive, which would enable its adoption. Meanwhile, a few participants said there should be incentives given for waste disposal to encourage proper disposal.
For example,

> *"Rewarding our people for proper disposal of plastics waste and maybe when they drop plastic in their bin they will be given 100naira or 200naira I think one of many ways anyway for the promotion of that is to reward people for proper disposal." (CE012)*

This resonates with the previous findings, which reported that to encourage recycling among families, a pilot project was launched, a virtual reward token named RECICLOS was developed, and a web app prototype was used to register the recycled plastic. Incentives and rewards were used to enhance recycling habits. Ten per cent of the targeted demographic (1053 households) had signed up for the program at the end of the six-week test study (Gibovic and Bikfalvi, 2021). Furthermore, most participants said there should be a pilot sample of roads constructed using plastic waste in Nigeria. This would help to hasten its adoption; moreover, a few participants said international investors could help fund the pilot trial."We need to have some pilot projects some showcase project around the country where people can easily go and confirm that indeed plastic can be used for road construction." (CBE008). This resonates with the recommendation by Suaryana et al. (2018), who said since plastic roads are still new, real-time performance assessment should be done by countries using less than 1km as prototypes.

4.2 Potential Barriers to the Adoption of Plastic Waste for Road Construction.

The potential barriers hindering the adoption of plastic waste for road construction, according to the participants, range from technical know-how, funding, evidence of usage, quality, war from competitions/political will, equipment, Standardized methodology, Availability of huge plastic waste, Knowledge gap, Learn new things. Some of the participants said it is difficult for people to learn new things. They would prefer their regular method of construction; in addition, a few participants said there is a gap in knowledge because there is a need for hands-on beyond the classroom. Some participants said availability and cost of equipment is a big barrier to adopting the technology, while some other participants said the lack of political will from the government to accept the technology and competition frustrates its adoption.

> *"I think the stakeholders will be actually willing to adopt. But the biggest issue will be on. The governance structure and the political aspect, I think that's where the biggest issue would be." (EN003)*

Besides, few participants said funding is a main challenge for adopting this innovation, whereas some participants said there are no expertise in that area and there is need to know the technicality behind the innovation. Additionally, some participants are concerns about quality performance as compared to conventional materials, similarly, some said one of the hindrance is not seeing evidence of where it has been used to know its durability and failure pattern.

> *"One of the major challenge regarding this plastic is on material performance because it needs to pass the test, you understand it needs to pass a technical feasibility test and also regulatory test it has to go through bodies that has to certify that this plastic use for road is durable and is gonna last a test of time so a regulatory body has to certify that this would work." (CE007)*

This aligns with the recommendation from Abd Karim *et al.* (2023), who said that more research and evaluation should be done to fully understand the sustainability and viability of constructing roads using plastic asphalt. Similarly, using plastic waste for road construction is hindered by not enough feasibility and compatibility evidence (Abukhettala and Fall, 2021).
Furthermore, few participants were concerned about the availability of plastic waste in large volumes for construction, while some participants said the potential to adopt it in Nigeria is low because there are no guidelines and standardization.

> *"The thing is that when we construct roads, we are talking of 100KMs 150KMs 200KMs I don't know, can you imagine how long this thing is? from Ibadan to Oyo is just 40KMs. From Ibadan to Lagos is just like 60KMs but when you are doing a project of 100KMs 150KMs imagine the kind of material you will be using for construction. Now if you want to use plastic waste as, is it full replacement or partial replacement? How many plastic waste materials do you have that is going to fit into this kind of project to complete their road? do you understand? How available is this plastic waste you are even talking about for this stretch of road?" (CE010)*

This opinion is in line with the findings of Oropeza (2019) who reported that in spite of exchanging 500kg of one-use plastic for 4g gold coins with the residents, the plastic road construction project literally failed after a year due to insufficient plastic.

Additionally,

> *"The potential to adopt it in Nigeria is low and I don't see it happening and the reason I don't see it happening is because there is no guideline or framework for such. So, when it comes to road construction, there are guidelines for virtually all the stages of the project and for all activity. So, when it comes to using plastic in road construction, there are no guidelines." (EN003)*

This resonates with previous study that says if plastic roads demonstrate to be a sustainable practice, standards are needed to enable the modification of asphalt/bitumen and recycled plastics, promote plastic road construction by convincing local authorities and meet the requirement of asphalt/bitumen producers (Enfrin and Giustozzi, 2022).

5 Conclusions and Further Research

This study aimed to identify and evaluate the barriers and enablers of using and adopting plastic waste for road construction. The findings showed that awareness, government policy, lack of funding, technical know-how, political will, unavailability of equipment, standardized methodology, practical-knowledge gap and a sample trial are factors hindering the adoption of plastic waste for road construction in Nigeria. However, the enables include global warning concerns, government policies and environmental awareness. Since the awareness of using plastic waste for road construction is relatively low in Nigeria, a pilot test is required to evaluate its potential hazard, cost, and durability. This study contributes to sustainable road infrastructure practices in Nigeria by exploring an innovative use of plastic waste. It provides valuable insights for policymakers and the construction sector on the benefits, feasibility, and challenges of adopting waste-based materials in road construction, potentially informing a circular economy model within Nigeria's infrastructure development. A pilot would enable researchers to do more research in this area and present and thoroughly publicise their findings. The Nigerian government should develop policies for easy implementation of plastic waste in road construction and key stakeholders should be more willing to consider giving it a try. Further research is needed to thoroughly evaluate the financial feasibility of using plastic waste for road construction.

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