

Assessing the Economic, Social, and Environmental Impacts of Rigid Pavement Adoption on Major Federal Highways in Nigeria

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Abstract - Federal highways in Nigeria extend over thirty four thousand kilometres and have historically been constructed using flexible pavement systems due to their lower initial construction cost and relative ease of maintenance. Despite these advantages, persistent pavement failures, frequent rehabilitation works, and escalating maintenance expenditure have become widespread as a result of increasing traffic volumes, heavy axle loads, weak enforcement of axle load regulations, and harsh climatic conditions. These challenges have prompted a gradual policy shift by the Federal Government of Nigeria towards the adoption of rigid pavement systems on major federal highways. Rigid pavements provide superior structural capacity, improved load distribution, resistance to rutting, and longer service life when compared with flexible pavements. However, concerns remain regarding their economic feasibility, social acceptability, environmental sustainability, and institutional readiness within the Nigerian context. This study empirically examines the economic, social, environmental, and institutional impacts of rigid pavement adoption on major federal highways in Nigeria. A cross sectional survey design was employed involving one hundred stakeholders comprising engineers, contractors, policymakers, transport operators, road users, and host community members. Data were collected using structured questionnaires and complemented with semi structured interviews. Quantitative data were analysed using descriptive statistics, Pearson correlation analysis, and multiple regression analysis, while qualitative data were analysed using thematic analysis. The findings indicate that although rigid pavements are perceived to offer long term durability and reduced maintenance requirements, high initial construction costs, weak institutional monitoring, limited stakeholder engagement, and environmental concerns associated with cement production significantly influence stakeholder acceptance. The study concludes that rigid pavement adoption in Nigeria is not solely a technical decision but a policy driven process requiring integrated economic planning, institutional strengthening, environmental innovation, and inclusive stakeholder participation.

I. INTRODUCTION

Transportation infrastructure plays a central role in the economic and social development of Nigeria, with road transport accounting for the dominant share of passenger and freight movement nationwide. Federal highways form the backbone of the national transport network, linking major economic centres, industrial zones, seaports, and international borders. These highways facilitate trade, regional integration, access to markets, and the delivery of essential services (Olowosulu et al. 2021).

Historically, flexible pavements have been the predominant pavement type used on federal highways in Nigeria due to their relatively low initial construction cost and ease of maintenance. However, the long term performance of flexible pavements has been severely compromised by increasing traffic demand, frequent overloading, weak enforcement of axle load regulations, and adverse climatic conditions characterised by high temperatures and intense rainfall (Emmanuel, Igwe, and Uche 2021). These factors have resulted in widespread pavement distress including rutting, cracking, pothole formation, and premature structural failure (Adeke, Kanyi, and Olawuyi 2021).

The frequent failure of flexible pavements has led to escalating maintenance expenditure, traffic disruptions, increased vehicle operating costs, and reduced safety for road users (Abubakar 2024). In response to these challenges, the Federal Government of Nigeria has increasingly promoted the use of rigid pavement systems on selected major trunk and coastal highways subjected to heavy traffic and high axle loads.

Rigid pavements, constructed primarily with Portland cement concrete, offer superior structural performance, better load distribution, resistance to deformation, and longer service life when compared

with flexible pavements (Walubita et al. 2022). Despite these advantages, the adoption of rigid pavements has generated debate among stakeholders regarding economic affordability, environmental impacts associated with cement production, social implications such as noise and ride comfort, and the institutional capacity required for effective implementation. Most existing studies in Nigeria have focused on technical performance and cost comparison between pavement types, with limited empirical assessment of the combined economic, social, environmental, and institutional implications. This study addresses this gap.

II. LITERATURE REVIEW

Pavements are structural systems designed to support traffic loads and distribute stresses safely to the underlying subgrade while providing durability, safety, and ride comfort (Ziar et al. 2023). Flexible pavements consist of multiple layers including a bituminous surface, base course, sub base, and subgrade. Load distribution in flexible pavements occurs gradually through the layered system, making them adaptable to varying subgrade conditions. However, flexible pavements are vulnerable to deformation, moisture damage, oxidation, and thermal cracking under heavy traffic and adverse climatic conditions (Tasnim et al. 2021).

Rigid pavements are typically constructed using Portland cement concrete slabs placed over a prepared sub base and subgrade. Due to their high stiffness and flexural strength, rigid pavements distribute loads over a wider area, resulting in reduced stress on the subgrade and minimal surface deflection. This structural behaviour makes rigid pavements more resistant to rutting and structural failure under heavy axle loads (Manjunatha et al. 2024).

From an economic perspective, pavement selection requires evaluation of both initial construction cost and long term life cycle cost. Life Cycle Cost Analysis provides a systematic framework for comparing pavement alternatives by incorporating construction, maintenance, rehabilitation, and user costs over the pavement service life (Adewumi, Sulaiman, and Shola 2024). Although rigid

pavements generally have higher initial construction costs than flexible pavements, their longer service life and reduced maintenance requirements may result in comparable or lower total life cycle costs, particularly on high traffic corridors (Badiru, Ademola, and Dambo 2023).

Social considerations related to pavement selection include road safety, user comfort, noise levels, employment generation, and community acceptance. While rigid pavements reduce pothole formation and structural failure, higher tyre pavement noise and surface glare have been identified as potential disadvantages affecting user comfort and nearby communities (Freitas et al. 2018; Kappou et al. 2022).

Environmental sustainability is a major concern in pavement construction. Cement production is a significant source of global carbon dioxide emissions, raising environmental concerns regarding rigid pavements (Ding et al. 2023). However, reduced maintenance frequency, longer service life, and improved surface reflectivity may result in lower cumulative environmental impacts over the pavement life cycle (Elizondo Martínez et al. 2018).

III. METHODOLOGY

The study adopted a positivist research philosophy and employed a cross sectional survey design. The study population comprised engineers, contractors, policymakers, transport operators, road users, and host community members involved in or affected by federal highway pavement decisions.

A sample size of one hundred respondents was selected using a combination of stratified and purposive sampling techniques to ensure adequate representation of all stakeholder groups. Primary data were collected using structured questionnaires based on a five point Likert scale measuring economic, social, environmental, and institutional variables. Semi structured interviews were conducted to provide qualitative insights.

Quantitative data were analysed using descriptive statistics, Pearson correlation analysis, and multiple regression analysis, while qualitative data were analysed using thematic analysis.

IV. RESULTS AND DISCUSSION

Table 1: Socio Demographic Characteristics of Respondents

Variable	Category	Frequency	Percentage (%)
Gender	Female	46	46.0
	Male	36	36.0
	Prefer not to say	18	18.0
Age Group	18 - 30	13	13.0
	31 - 40	51	51.0
	41 – 50	36	36.0
Job Category	Engineer	20	20.0
	Contractor	10	10.0
	Policymaker	10	10.0
	Transport Operator	10	10.0
	Road User	40	40.0
	Community Member	10	10.0
Experience	> 5 years	28	28.0
	11 -20 years	21	21.0
	> 20 years	7	7.0

The demographic distribution indicates that respondents were drawn from economically active age groups with sufficient professional and user experience to provide informed opinions.

Table 2: Economic Impact Perceptions of Rigid Pavement Adoption

Variable	Mean	Std. Deviation
Rigid pavements are more cost-effective	1.81	0.94
Initial cost of construction	4.16	1.37
Reduced maintenance justifies higher initial cost	4.13	1.36
Adoption supports local industries	1.70	0.92

The results show strong agreement that high initial construction cost is a major barrier to adoption, although respondents recognised the long term economic benefits of reduced maintenance.

Table 3: Social Impact Perceptions

Statement	Mean	Standard Deviation
Rigid pavements reduce potholes and improve safety	3.42	1.21
Rigid pavements improve ride comfort	3.08	1.26
Tyre pavement noise is higher	3.67	1.19
Community consultation was adequate	2.89	1.34

These findings indicate mixed social perceptions, with safety benefits recognised but concerns regarding noise and stakeholder engagement remaining significant.

Table 4: Environmental and Institutional Impact Perceptions

Statement	Mean	Standard Deviation
Cement production increases greenhouse gas emissions	4.21	1.15
Rigid pavements reduce long term environmental impact	3.44	1.27
Environmental impact assessment is necessary	4.02	1.22
Institutional capacity affects project success	4.08	1.19

Environmental sustainability and institutional governance emerged as critical determinants of stakeholder acceptance.

V. CONCLUSION

This study examined the economic, social, environmental, and institutional impacts of rigid pavement adoption on major federal highways in Nigeria. The findings demonstrate that although rigid pavements offer significant long term durability and maintenance advantages, their adoption is constrained by high initial construction costs, environmental concerns associated with cement production, limited stakeholder engagement, and weak institutional governance.

The study concludes that rigid pavement adoption in Nigeria should be approached as a holistic policy decision rather than a purely technical choice. Effective implementation requires institutionalisation of life cycle cost analysis, strengthening of monitoring and governance frameworks, adoption of environmentally sustainable construction materials, and inclusive stakeholder participation throughout the project life cycle.

REFERENCES

- [1] Abubakar, M. 2024. Influence of land use and traffic on road safety along Jimeta Bypass. *Rafidain Journal of Engineering Sciences* 2 (1): 165–176.
- [2] Adeke, P., I. Kanyi, and M. Olawuyi. 2021. Correlation analysis of flexible road pavement surface condition and subgrade strength. *Aksaray University Journal of Science and Engineering* 5 (2): 65–77.
- [3] Adewumi, R., W. Sulaiman, and A. Shola. 2024. Life cycle economic comparison between rigid and flexible pavements. *Engineering and Technology Journal*.
- [4] Badiru, A., A. Ademola, and H. Dambo. 2023. Infrastructure expenditure and economic growth in Nigeria. *Journal of Economic Sciences* 2 (1): 53–68.
- [5] Ding, X., G. Guihong, C. Bori, C. Zheng, and D. Longting. 2023. Pavement structure and environmental performance. *Frontiers in Energy Research* 11.
- [6] Elizondo Martínez, E., V. Andrés Valeri, L. Juli Gándara, and J. Rodríguez Hernández. 2018. Porous concrete pavements and sustainability. *Proceedings* 2 (23): 1453.
- [7] Emmanuel, U., O. Igwe, and U. Uche. 2021. Investigation into road failure along Sagamu Papalanto highway. *Geoenvironmental Disasters* 8 (1).
- [8] Freitas, E., F. Martins, A. Oliveira, I. Segundo, and H. Torres. 2018. Traffic noise and pavement distress. *Applied Acoustics* 138: 147–155.
- [9] Kappou, G., et al. 2022. Tyre pavement noise and user comfort. *Transportation Research Record*.
- [10] Manjunatha, M., et al. 2024. Rigid pavement performance under heavy traffic. *Applied Sciences*.
- [11] Olowosulu, Y., et al. 2021. Federal road infrastructure and economic growth in Nigeria. *Journal of Transport and Supply Chain Management*.
- [12] Walubita, L. F., et al. 2022. Performance evaluation of rigid pavements. *Construction and Building Materials*.
- [13] Ziar, H., et al. 2023. Comparative performance of pavement systems. *Sustainability* 15 (6): 5124.