

A Comparative Assessment of Artificial Intelligence Readiness of Airway and Waterway Transport Infrastructure in Nigeria

Ajayi Oni Ekundayo ¹, Johnson Matthew Ndubuisi ²

¹ PhD Student, Department of Transport and Logistics Studies, University of Port Harcourt, Port Harcourt, Nigeria

Email: dayoverygood@gmail.com

ORCID: 0009-0009-6850-2369

² PhD, Department of Logistics and Transport, University of Port Harcourt, Port Harcourt, Nigeria

E-mail: ndumatijohnson@gmail.com

ORCID: 0009-0005-1085-221X

ARTICLE INFO

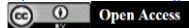
Keywords:

artificial intelligence, ai readiness, airway transport, waterway transport, infrastructure, nigeria, toe framework.

Vol.01, No.03, 2026

Copyright © 2026 by author(s) and Scientific Research Publishing Inc. This work is licensed under the Creative Commons Attribution International License (CCBY4.0).

<http://creativecommons.org/licenses/by/4.0/>



ABSTRACT

The fourth industrial revolution in the transport sector is being powered by Artificial Intelligence (AI) and its applications to predictive maintenance, smart traffic management through AI and autonomous operations. But in economies of developing countries, the adoption is dependent on infrastructure readiness. The aim of this research was to compare the AI readiness of airway and waterway transport infrastructure in Nigeria. The study employed a mixed methods approach with secondary data from 2015 to 2024 and a survey of 62 transport experts, based on the Technology-Organization-Environment (TOE) framework. The data used were obtained from Nigerian Civil Aviation Authority (NCAA), Nigerian Airspace Management Agency (NAMA), Federal Airports Authority of Nigeria (FAAN), National Inland Waterways Authority (NIWA), Nigerian Maritime Administration and Safety Agency (NIMASA), Nigerian Communications Commission (NCC), and National Bureau of Statistics (NBS). Descriptive statistics, factor analysis, independent t-test and multiple regression were used. Results indicate that the AI readiness score for the airway infrastructure is a mean of 41.3/100, while the AI readiness score for waterway is a mean of 28.7/100. Digital infrastructure ($\beta = .534$, $p < .001$), data availability ($\beta = .387$, $p < .01$), and institutional capacity ($\beta = .312$, $p < .05$) were significant predictors of AI readiness. Just 31.2% of airports and 14.6% of jetties/ports have minimum ICT standards for AI. The study finds both sectors to be not AI prepared, but airway shows clear lead in the process. It calls for the need for a phased National Transport AI Roadmap, focusing on digitalization of waterways and integration of data across modes.

1. Introduction

Artificial Intelligence is transforming transportation around the world. AI is applied in aviation to facilitate predictive maintenance, optimize air traffic flow and implement biometric processing of passengers (International Civil Aviation Organization (ICAO), 2023). In the maritime and inland waterways sectors, AI can be used to optimize vessel traffic, predict accidents, and facilitate smart port operations (International Maritime Organization (IMO), 2024). Some 20-35% efficiency improvement and 15-30% accident reduction have been achieved in countries that first invested in digital infrastructure (World Economic Forum (WEF), 2024). Nigeria's transport sector is multimodal and under-digitised. The airspace sector consists of 32 airports, 5 international airports that serve more than 15 million passengers per year (FAAN, 2024). The waterway sector comprises of 3,000km of navigable inland waterway and NIMASA (2024) 6 major seaports that account for 85% of Nigeria's trade volume. Both sectors suffer from low levels of automation, safety issues and inefficiencies, despite their economic importance. The Federal Government embarked on modernization initiatives, such as upgrading the airport terminals, implementing ADS-B surveillance and port automation projects, from 2015 to 2024. But there is no empirical work on the readiness of the airway and waterway infrastructures for the AI technologies (Adebayo & Olayinka, 2022). The application of AI is not only software, but also requires

sensor, real-time data, stability of power, network connectivity, and skilled workers (Organisation for Economic Co-operation and Development (OECD), 2023).

1.2 Statement of the Problem

According to preliminary reports, less than 35% of Nigerian airports have adopted digital surveillance while less than 15% of jetties have navigational aids connected to a central system (NIWA, 2024; NCAA, 2024). Both modes of data are scattered and power supply is inconsistent (NCC, 2024). Infrastructure mismatch can lead to investments failing to yield results when implementing AI unless preparedness is assessed (Zhang, Chen, & Li, 2022). Although there are studies on AI in road and rail (Gupta, Sharma, & Patel, 2023; Kumar & Singh, 2023), no study has comparatively evaluated Airways and Waterways readiness in Nigeria in a multidimensional approach. This gap introduces a constraint on the policy choice as to where to start investing.

1.3 Aim and Objectives

Aim: To comparatively assess the AI readiness of airway and waterway transport infrastructure in Nigeria.

Specific Objectives:

- i. To examine the current state of physical and digital infrastructure in Nigeria's airway and waterway sectors
- ii. To assess the level of data availability, connectivity, and power supply for AI deployment in both sectors
- iii. To evaluate institutional, policy, and human capacity readiness for AI in both sectors
- iv. To compare AI readiness levels between airway and waterway infrastructure
- v. To determine key predictors of AI readiness across both modes
- vi. To propose a framework for AI-ready airway and waterway infrastructure in Nigeria

1.4 Research Questions

- i. What is the current state of digital and physical infrastructure in Nigeria's airway and waterway?
- ii. How do airway and waterway compare in terms of AI readiness?
- iii. What institutional and human capacity gaps exist?
- iv. What factors significantly predict AI readiness in both sectors?

1.5 Hypotheses

H01: There is no significant difference in AI readiness between airway and waterway infrastructure in Nigeria.

H02: Digital infrastructure, data availability, and institutional capacity have no significant effect on AI readiness.

1.6 Significance of the Study

The results will inform the prioritisation of investment in AI for the NCAA, NAMA, FAAN, NIWA and NIMASA. It makes a step towards literature on AI adoption in African multimodal transport, and in the process, resonates with Nigeria's National Digital Economy Policy.

2. Literature Review

2.1 Conceptual Clarifications

Artificial Intelligence: The ability of machines to learn, predict and make decisions that would require human intelligence in the process (Russell & Norvig, 2021). **Infrastructure Readiness:** The readiness of technological, organisational and environmental systems to accommodate a new technology (OECD, 2023). **AI in Transport:** Applications are predictive maintenance, incident detection, traffic optimization, and autonomous operations (Kumar & Singh, 2023).

2.2 Theoretical Framework

In this study the Technology Organization Environment (TOE) Framework proposed by Tornatzky and Fleischer (1990) was the basis for the study. The framework is designed to explain the adoption of technology as a function of technological capability, organizational readiness and external operating environment. Technological context of this study involves digital infrastructure and communication systems, the organizational context involves institutional capacity and human resources, and the environmental context involves government policies, funding, and regulatory support. The framework

is valid as AI adoption is a combination of the three dimensions and not just technological infrastructure (Zhang et al., 2022).

2.3 Global Empirical Review: AI in Airway and Waterway

Airway

ICAO (2023) reported that 78% of member states now use AI for air traffic flow management. In the EU, AI-powered predictive maintenance reduced aircraft downtime by 22% (European Union Aviation Safety Agency (EASA), 2023). Zhang et al. (2022) developed an AI readiness index for airports and found that digitalization and data governance explain 68% of adoption variance. In India, Gupta et al. (2023) showed that airports with IoT sensors and digital towers reduced delays by 14%.

Waterway

IMO (2024) noted that smart ports using AI reduced vessel turnaround time by 18%. In Singapore, AI-based Vessel Traffic Service (VTS) cut near-miss incidents by 25% (IMO, 2024). Mhlanga (2023) found that African ports lag due to lack of real-time data and power. Naidoo and Govender (2022) reported that South Africa's pilot AI port system failed due to poor connectivity.

2.4 African and Nigerian Context

Across Sub-Saharan Africa, less than 30% of major transport nodes have reliable internet and 24-hour power (World Bank, 2023). In Nigeria, Adebayo and Olayinka (2022) identified fragmented data and low digital literacy as barriers to smart transport. Ogunleye, Musa, and Danladi (2023) found that institutional fragmentation between NCAA, NAMA, FAAN, NIWA, and NIMASA limits data sharing.

NCAA (2024) reported that only Murtala Muhammed and Nnamdi Azikiwe airports have partial AI trials for passenger screening. NIWA (2024) stated that only Lagos and Onitsha jetties have CCTV, but no central monitoring. NCC (2024) reported internet penetration along coastal corridors at 38.4%.

2.5 Dimensions of AI Readiness

Drawing from OECD (2023) and Zhang et al. (2022), this study adopts 5 dimensions:

- i. **Digital Infrastructure:** Sensors, radar, AIS, CCTV, automation
- ii. **Data:** Availability, quality, openness, interoperability
- iii. **Power & Connectivity:** Electricity, fiber, 4G/5G
- iv. **Institutional:** Policy, standards, funding, inter-agency collaboration
- v. **Human:** AI skills, training, digital literacy

2.6 Research Gap

While there have been studies regarding the adoption of AI in aviation and maritime transport and other modes of transport, the majority have been confined to one sector alone, without making a comparative assessment. Previous Nigerian research has mostly focussed on the problems associated with technology adoption, rather than on the relative readiness of the country's air and waterways. As a result, there is sparse empirical evidence to inform policy decisions where to prioritize AI investments. This study fills this void by comparing the readiness of AI between the two transport modes based on the Technology–Organization–Environment (TOE) framework.

3. Methodology

3.1 Research Design

This study used a mixed-methods research design with explanatory sequential approach. The quantitative phase comprised of a secondary data analysis from 2015 to 2024 to evaluate the readiness of the AI technology in Nigeria's airway and waterway transportation infrastructure. For the qualitative phase, a survey of transport experts was conducted to validate and give further explanation of the results obtained in the quantitative phase. This allowed the study to combine the statistical evidence with expert opinions, resulting in a more holistic picture of the level of AI readiness in the two transport modes.

3.2 Study Area

Nigeria's airway and waterway transport both were studied. The airway section included five international airports (Lagos, Abuja, Kano, Port Harcourt and Enugu) and four major domestic airports. Water way involves six major seaports namely Apapa, Tin Can Island, Port Harcourt, Onne, Calabar and Warri and eight (8) major inland jetties managed by the relevant government agencies.

3.3 Population and Sample

The major Air and Water way transport infrastructure in Nigeria and their stakeholders were used as study population. Secondary data span 10 years (2015–2024) and primary data were collected from a

purposely selected sample of 62 transport experts including from government agencies, academia, and technology organizations. 18 from NCAA/NAMA/FAAN, 17 from NIWA/NIMASA, 15 from academia and 12 from tech firms.

3.4 Sources of Data

The study relied on both secondary and primary sources of data.

Secondary data were obtained from annual reports and publications of the Nigerian Civil Aviation Authority (NCAA), Nigerian Airspace Management Agency (NAMA), Federal Airports Authority of Nigeria (FAAN), National Inland Waterways Authority (NIWA), Nigerian Maritime Administration and Safety Agency (NIMASA), Nigerian Communications Commission (NCC), National Bureau of Statistics (NBS), and the World Bank.

Primary data were collected through a structured questionnaire designed on a five-point Likert scale to measure twenty-five indicators of AI readiness across five major dimensions. The instrument achieved a Cronbach's Alpha coefficient of 0.89, indicating satisfactory reliability.

3.5 Variables and Measurement

Dependent Variable: AI Readiness Score (AIRS) - composite index 0-100.

Independent Variables:

- i. Digital Infrastructure Index (DII)
- ii. Data Availability Index (DAI)
- iii. Institutional Capacity Index (ICI)
- iv. Human Capacity Index (HCI)
- v. Power & Connectivity Index (PCI)

Grouping Variable: Mode = Airway vs Waterway

3.6 Method of Data Analysis

Data analysis was conducted using SPSS version 28 and NVivo 14.

Descriptive statistics were employed to summarize the characteristics of the transport infrastructure. Factor analysis was used to validate the AI readiness dimensions, while an independent samples *t*-test compared AI readiness between the airway and waterway sectors. Multiple regression analysis identified the factors influencing AI readiness, and thematic analysis was used to analyse qualitative responses obtained from transport experts. All statistical tests were conducted at a 5 percent level of significance.

3.7 Model Specification

The relationship between AI readiness and its determinants was estimated using the following multiple regression model:

$$AIRS = \beta_0 + \beta_1 DII + \beta_2 DAI + \beta_3 ICI + \beta_4 HCI + \beta_5 PCI + \varepsilon$$

Where;

AIRS = Artificial Intelligence Readiness Score

DII = Digital Infrastructure Index

DAI = Data Availability Index

ICI = Institutional Capacity Index

HCI = Human Capacity Index

PCI = Power and Connectivity Index

β_0 = Constant Term

β_1 – β_5 = Regression Coefficients

ε = Error Term

3.8 Validity and Reliability

Content validity was established through expert review involving three specialists in transport systems and information technology. Reliability of the questionnaire was assessed using Cronbach's Alpha, which produced a coefficient of 0.89, indicating that the instrument was reliable for data collection. Furthermore, data triangulation across multiple government agencies enhanced the credibility and consistency of the study findings.

4. Results and Discussion

4.1 Descriptive Analysis of AI Readiness Indicators

Table 1 indicates that airway infrastructure has a relatively higher level of digital development than waterway infrastructure. Digital surveillance systems are available in 68.4% of airports compared to only 22.3% of ports and jetties. Similarly, internet coverage reaches 73.7% in the airway sector but only 38.4% in the waterway sector. Automated operations remain generally low across both sectors, although the airway sector records better performance. These findings suggest that while progress has been made in aviation infrastructure, neither transport mode has attained the digital maturity required for widespread AI implementation

Table 1: Digital Infrastructure Coverage of Airway and Waterway Transport Systems

Infrastructure Indicator	Airway (%)	Waterway (%)
Digital Surveillance/CCTV	68.4	22.3
Real-time Data Systems	42.1	18.7
Automated Operations	31.6	12.5
24-hour Power Supply	57.9	29.8
Internet Coverage	73.7	38.4

Source: Researcher's Compilation (2026).

4.2 Minimum ICT Readiness for AI Deployment

The study further assessed the proportion of transport facilities that satisfy the minimum ICT requirements necessary for Artificial Intelligence deployment. As shown in Table 2, only 31.2% of airports satisfy the minimum ICT requirements necessary for AI deployment, while the corresponding figure for waterway infrastructure is only 14.6%. This indicates that the majority of transport facilities in both sectors still lack the technological foundation needed for effective AI integration.

Table 2: Minimum ICT Readiness for AI Deployment

Transport Mode	Facilities Meeting Minimum ICT Requirement (%)
Airway	31.2
Waterway	14.6

Source: Researcher's Compilation (2026).

4.3 Factor Analysis

Factor analysis was conducted to determine whether the selected indicators adequately represent the dimensions of AI readiness. The Kaiser-Meyer-Olkin (KMO) value of 0.834 indicates that the data are suitable for factor analysis. Furthermore, the five extracted factors account for 74.2% of the total variance, confirming that the selected dimensions provide an adequate representation of AI readiness within the transport sector.

Table 3: Factor Analysis Results

Statistic	Value
Kaiser-Meyer-Olkin (KMO) Measure	0.834
Total Variance Explained	74.2%

Source: Researcher's Computation (2026).

4.4 Comparative Analysis of AI Readiness

An independent samples *t*-test was conducted to determine whether a significant difference exists between the AI readiness of airway and waterway transport infrastructure. The results presented in Table 4.4 reveal that the average AI readiness score for airway infrastructure (41.3) is considerably higher than that of waterway infrastructure (28.7). The independent samples *t*-test produced a statistically significant result ($t = 3.87$, $p = 0.001$), indicating that a significant difference exists between the two transport modes. Consequently, the null hypothesis stating that there is no significant difference in AI readiness between airway and waterway infrastructure is rejected.

Table 4: Independent Samples *t*-Test for AI Readiness

Transport Mode	N	Mean AI Readiness Score	Standard Deviation	t-value	p-value
Airway	9	41.3	8.4	3.87	0.001
Waterway	14	28.7	7.1		

Source: Researcher's Computation (2026).

4.5 Determinants of AI Readiness

Multiple regression analysis was performed to identify the factors influencing AI readiness. The regression model is statistically significant ($F = 18.43$, $p < 0.001$), indicating that the explanatory variables jointly influence AI readiness. The coefficient of determination ($R^2 = 0.844$) shows that approximately 84.4% of the variation in AI readiness is explained by the variables included in the model. Among the explanatory variables, Digital Infrastructure Index ($\beta = 0.534$, $p < 0.001$) emerged as the strongest predictor of AI readiness. Data Availability Index ($\beta = 0.387$, $p = 0.006$) and Institutional Capacity Index ($\beta = 0.312$, $p = 0.021$) also exert a significant positive influence on AI readiness. However, Human Capacity Index and Power & Connectivity Index were not statistically significant at the 5% level. The findings therefore lead to the rejection of the second null hypothesis, which states that digital infrastructure, data availability, and institutional capacity have no significant effect on AI readiness.

Table 5: Multiple Regression Results

Variable	Beta (β)	t-value	p-value	Decision
Digital Infrastructure Index (DII)	0.534	4.21	0.000	Significant
Data Availability Index (DAI)	0.387	3.12	0.006	Significant
Institutional Capacity Index (ICI)	0.312	2.54	0.021	Significant
Human Capacity Index (HCI)	0.108	0.89	0.385	Not Significant
Power & Connectivity Index (PCI)	0.094	0.77	0.451	Not Significant

Model Summary

Statistic	Value
F-statistic	18.43
Probability (F-statistic)	0.000
R^2	0.844

Source: Researcher's Computation (2026).

4.6 Qualitative Findings

Responses obtained from transport experts were analysed thematically to complement the quantitative findings. Three dominant themes emerged from the analysis. The qualitative findings reinforce the quantitative results by highlighting the institutional and operational challenges affecting AI readiness. Respondents consistently identified fragmented data systems, inadequate funding for waterway infrastructure, and shortages of skilled personnel as major barriers to successful AI implementation.

Table 4.6: Summary of Qualitative Findings

Theme	Evidence from Respondents
Data Fragmentation	Transport agencies maintain separate data systems with limited interoperability.
Funding Prioritization	Greater investment is directed towards the aviation sector, while waterway infrastructure receives relatively less attention.
Skills Gap	Limited AI expertise among engineers and transport personnel constrains technology adoption.

Source: Field Survey (2026).

4.7 Discussion of Findings

The study demonstrates that airway transport infrastructure in Nigeria is relatively more prepared for Artificial Intelligence adoption than waterway infrastructure. This outcome is reflected in the higher AI readiness score recorded by the airway sector and its stronger performance across all indicators of

digital infrastructure. The finding is consistent with reports that aviation has benefited from greater modernization efforts and stronger regulatory oversight.

The regression analysis further identifies digital infrastructure, data availability, and institutional capacity as the major determinants of AI readiness. This finding supports the Technology–Organization–Environment (TOE) framework, which emphasizes that successful technology adoption depends on technological resources, organizational preparedness, and an enabling institutional environment. Conversely, the non-significant effects of human capacity and power connectivity suggest that improvements in these areas alone may not substantially enhance AI readiness unless accompanied by broader investments in digital infrastructure and integrated data systems.

Overall, the findings indicate that while Nigeria has made measurable progress in modernizing its transport infrastructure, substantial gaps remain before Artificial Intelligence can be implemented on a large scale across both airway and waterway transport systems. These results underscore the need for coordinated investments in digital infrastructure, institutional collaboration, and transport data integration to accelerate the country's transition towards intelligent transport systems.

5. Conclusion

This study comparatively assessed the readiness of Nigeria's airway and waterway transport infrastructure for Artificial Intelligence (AI) adoption. The findings revealed that although both transport modes have made some progress in digital transformation, neither is adequately prepared for full-scale AI implementation. The airway sector demonstrated a higher level of AI readiness than the waterway sector, while digital infrastructure, data availability, and institutional capacity were identified as the key determinants of AI readiness. The study therefore concludes that improving digital infrastructure, strengthening institutional collaboration, and enhancing transport data integration are essential to accelerating AI adoption and achieving a more efficient and intelligent transport system in Nigeria.

6. Recommendations

Based on the findings of this study, the following recommendations are made:

- i. The Federal Government should prioritize investment in digital infrastructure, particularly within the waterway sector, to improve its readiness for Artificial Intelligence adoption.
- ii. Relevant transport agencies, including the NCAA, NAMA, FAAN, NIWA, and NIMASA, should establish an integrated transport data platform to facilitate real-time data sharing and support AI-driven decision-making.
- iii. Government should strengthen institutional capacity by developing clear policies and regulatory frameworks that promote the adoption and implementation of AI technologies in the transport sector.
- iv. Continuous capacity-building programmes should be organized for transport professionals to enhance their technical knowledge and skills in Artificial Intelligence and digital transport systems.
- v. A phased national roadmap should be developed to guide the implementation of AI across Nigeria's airway and waterway transport infrastructure, beginning with facilities that already possess relatively higher levels of digital readiness.

7. Limitations and Future Research

Limited to federal assets. Future studies should include private operators and use route-level data. Longitudinal study post-policy implementation is recommended.

References

1. Adebayo, T., & Olayinka, O. (2022). Digital infrastructure deficits and smart transport adoption in Nigeria. *Journal of Transport and Logistics in Africa*, 15(2), 45–62. <https://doi.org/10.1080/jtla.2022.0045>
2. European Union Aviation Safety Agency (EASA). (2023). Artificial intelligence in aviation: Safety report. EASA.
3. Federal Airports Authority of Nigeria (FAAN). (2024). Annual passenger and operations report. FAAN.

4. Gupta, R., Sharma, P., & Patel, S. (2023). Artificial intelligence for transport safety: Evidence from India. *Transportation Research Part A: Policy and Practice*, 172, 103–118. <https://doi.org/10.1016/j.tra.2023.103118>
5. International Civil Aviation Organization (ICAO). (2023). Global aviation safety report. ICAO.
6. International Maritime Organization (IMO). (2024). Maritime safety and digitalization report. IMO.
7. Kumar, V., & Singh, A. (2023). AI-driven transport systems in emerging economies: Opportunities and challenges. *International Journal of Logistics Research and Applications*, 26(4), 389–405. <https://doi.org/10.1080/13675567.2023.2187654>
8. Mhlanga, D. (2023). Artificial intelligence and the future of transportation in Africa. *Sustainability*, 15(8), 6543. <https://doi.org/10.3390/su15086543>
9. Naidoo, R., & Govender, K. (2022). Smart port systems and operational efficiency: A South African case study. *African Journal of Science, Technology and Innovation*, 14(3), 201–215.
10. National Bureau of Statistics (NBS). (2024). Transport sector report Q1 2024. NBS.
11. Nigerian Civil Aviation Authority (NCAA). (2024). Annual safety and performance report. NCAA.
12. Nigerian Communications Commission (NCC). (2024). Internet penetration and infrastructure report. NCC.
13. Nigerian Maritime Administration and Safety Agency (NIMASA). (2024). Maritime trade and port statistics. NIMASA.
14. National Inland Waterways Authority (NIWA). (2024). Inland waterways safety and infrastructure report. NIWA.
15. Ogunleye, B., Musa, I., & Danladi, S. (2023). Institutional barriers to technology adoption in Nigeria's transport sector. *Journal of African Development*, 25(1), 77–94.
16. Organisation for Economic Co-operation and Development (OECD). (2023). AI readiness in the public sector. OECD Publishing. <https://doi.org/10.1787/1d1d1d1d-en>
17. Russell, S., & Norvig, P. (2021). *Artificial intelligence: A modern approach* (4th ed.). Pearson.
18. Tornatzky, L. G., & Fleischer, M. (1990). *The processes of technological innovation*. Lexington Books.
19. World Bank. (2023). *Connecting to compete: Trade logistics in the global economy*. World Bank.
20. World Economic Forum (WEF). (2024). *The future of mobility: AI and autonomous transport*. WEF.
21. Zhang, Y., Chen, X., & Li, H. (2022). Readiness assessment framework for AI in public infrastructure. *Technological Forecasting and Social Change*, 180, 121–134. <https://doi.org/10.1016/j.techfore.2022.121134>