Reengineering Inland Waterways: System Alignment and the Political Economy of Infrastructure Failure in Nigeria's Niger–Benue Corridor

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ABSTRACT

Infrastructure investment is widely viewed as a catalyst for economic transformation, yet many large-scale projects fail to generate sustained value. This paper examines this paradox through Nigeria's inland waterways, focusing on the 2009–2012 Warri–Baro dredging project. Despite substantial public investment and technical completion, the project failed to deliver commercial navigation or economic impact.

The paper advances a system alignment framework, arguing that infrastructure performance is a multiplicative function of three conditions: institutional coordination, demand anchoring, and technical sustainability ($P = I \times D \times T$). Using a qualitative case study and comparative analysis with China, USA, Netherlands, Europe, and Brazil, the study shows that the Warri–Baro project suffered from mis-sequenced investment, fragmented governance, the absence of binding cargo commitments, and a technically inadequate design in a dynamic hydrological environment. Political economy factors—corruption, policy discontinuity, elite capture—are specified as moderating conditions rather than core dimensions. These misalignments produced infrastructure that existed in form but not in function.

Comparative analysis demonstrates that successful inland waterways operate as integrated economic and institutional ecosystems. Evidence suggests that reengineering Nigeria's Niger–Benue system through coordinated governance, engineered infrastructure (locks and canalization rather than dredging), and industrial integration could reduce freight costs by 60–70% and generate US$1.08 billion in annual transport cost savings. The framework may be generalizable to rail, energy, and logistics networks, though this requires empirical testing beyond the waterways focus of the present study.

Keywords: Inland Waterways; Infrastructure Governance; Trade Corridors; Public–Private Partnership; Niger–Benue Corridor System; System Alignment; Nigeria.

INTRODUCTION

1.1 The Paradox of Infrastructure Investment

Transport infrastructure has long played a transformative role in reshaping economic geographies. Historic projects such as the opening of the Suez Canal—which reduced Asia–Europe shipping distances by roughly 40%—and the Panama Canal, which reconfigured interoceanic trade between the Atlantic and Pacific, illustrate how infrastructure does more than facilitate exchange; it actively restructures trade routes and spatial patterns of economic activity (Rodrik, 2004; Irwin, 2020). In the contemporary era, this logic has evolved further. Large-scale initiatives such as China's Belt and Road Initiative (BRI) demonstrate that infrastructure is increasingly deployed as a strategic instrument to rebalance regional trade, decongest logistics systems, and activate inland economies (Hillman, 2021; OECD, 2025).

Against this backdrop, infrastructure investment occupies a central place in development strategy, particularly in emerging economies seeking to reduce trade costs, stimulate industrialization, and enhance spatial integration (Calderón & Servén, 2014; World Bank, 2014). Yet, a persistent puzzle remains:

Why do large-scale infrastructure projects—often technically sound and politically prioritized—fail to generate sustained economic value?

This question is especially salient in the context of inland waterway development, where the gap between potential and realized performance is frequently pronounced (Banomyong, 2010; UNCTAD, 2018).

1.2 The Nigerian Case and Research Question

Nigeria's inland waterways—anchored on the Niger–Benue river system—epitomize this paradox. With an estimated 8,000–8,600 kilometres of navigable channels, the country possesses one of the most extensive inland waterway networks in Africa (National Inland Waterways Authority [NIWA], 2020, 2023). In principle, this system could function as a low-cost freight corridor, connecting inland production zones to coastal ports and regional markets. Inland water transport is globally recognized as significantly more cost-efficient for bulk cargo, often 30–60% cheaper than road transport on a per ton-kilometre basis (World Bank, 2014). In practice, however, Nigeria's inland waterways remain severely underutilized, operating at a fraction of their estimated capacity despite decades of policy attention and public investment (Ogunbodede, 2015; Ubogu, 2011).

While Nigeria's inland waterways comprise a broader network of rivers and channels, this paper focuses on the Niger–Benue corridor—the system's principal navigable axis—conceptualized here as the Niger–Benue Corridor System (NBCS). This framing emphasizes its role as an integrated economic and logistics corridor rather than a standalone river network.

The most ambitious attempt to unlock this potential—the Warri–Baro dredging project (2009–2012)—was conceived as a transformative intervention to restore navigability along the Lower Niger and catalyze multimodal transport integration (NIWA, 2013). Substantial financial resources were committed, and the project was declared technically completed. Yet, commercial navigation failed to materialize at scale, and inland ports remained largely idle, with anticipated economic benefits failing to materialize (Ogunbodede, 2015; Epelle, 2020). This outcome raises a critical analytical question:

Why do infrastructure investments of this scale fail to translate into functional economic systems?

This paper argues that such failures are manifestations of system misalignment rather than isolated technical shortcomings**.** It advances a *system alignment framework*, which posits that infrastructure generates sustained economic value only when three conditions are jointly satisfied: ***(i) institutional coordination, (ii) demand anchoring, and (iii) technical sustainability***. This perspective builds on and extends existing work on infrastructure-led development, which emphasizes complementarities between public capital, institutions, and market structures (Rodrik, 2004; Hausmann et al., 2008; Aghion et al., 2014). Where these elements are weak, absent, or poorly sequenced, infrastructure investments are unlikely to achieve utilization, even after physical completion.

Applying this framework to the Warri–Baro project, the paper demonstrates that its failure was rooted in four interrelated deficiencies: mis-sequenced investment (infrastructure preceding demand), fragmented governance across agencies, absence of binding cargo commitments, and reliance on technically inadequate dredging strategies in a highly dynamic hydrological environment (Ubogu, 2011; Ogunbodede, 2015; Ikejiofor et al., 2021). These factors collectively produced a situation in which infrastructure existed in form but not in function.

To situate this diagnosis within a broader analytical context, the paper undertakes a comparative assessment of global inland waterway systems. Cases examined include China's system-integrated river corridors, the United States' engineered Mississippi system, Europe's institutionally coordinated Rhine–Danube network, the Netherlands' hydro-engineered Rhine–Delta system, and Brazil's Paraguay–Paraná Waterway (Zhang & Chen, 2019; Jonkeren et al., 2019; European Commission, 2017; World Bank, 2016, CBDLA, 2019). Across these diverse contexts, a consistent pattern emerges: *successful inland waterway systems are not built as standalone projects, but as components of integrated economic, institutional, and engineering systems*.

The paper makes three contributions to the literature. First, it provides a system-level explanation of infrastructure failure, moving beyond conventional accounts that emphasize financing constraints or technical limitations (Calderón & Servén, 2014). Second, it introduces a sequencing perspective, highlighting the importance of aligning infrastructure investment with demand conditions and institutional capacity (Hausmann et al, 2008). Third, it develops a comparative framework linking Nigeria's experience to global best practices, generating policy-relevant insights for infrastructure planning in other developing economies.

Despite past failures, Nigeria retains unique advantages that make corridor reengineering viable. The Niger-Benue system traverses existing industrial nodes—including the Ajaokuta steel complex, Itakpe iron ore mine, Obajana cement plant, and Onitsha commercial hub—which could collectively generate an estimated 36-55 million tonnes of potential annual bulk cargo demand currently served inefficiently by road. The river network also offers one of Africa's few natural south-north waterways, connecting the Niger Delta to the Middle Belt and, via Baro, to landlocked Sahel markets. These geographic and industrial endowments differentiate the Nigerian case from generic infrastructure failures, providing a preexisting demand base that can anchor corridor viability if governance and engineering constraints are addressed.

1.3 Methodological Approach and Case Selection

This study adopts a qualitative case study methodology, complemented by illustrative quantitative analysis, to evaluate the performance constraints of inland waterway infrastructure and the applicability of the proposed framework. This approach is appropriate given the complex interaction of institutional, technical, and political economy variables that shape infrastructure outcomes and are not easily captured through purely econometric models. The Warri–Baro inland waterway corridor is selected as a critical case (Flyvbjerg, 2004). It represents a "most-likely" case: if the System Alignment Framework cannot explain failure under apparently favorable conditions—extensive natural endowment, substantial investment, sustained policy attention—its explanatory power is seriously challenged.

To mitigate the limitations of single-case analysis, the study draws analytical parallels with six international inland waterway systems: China (Yangtze/Pinglu), USA (Mississippi), Netherlands (Rhine–Delta), Europe (Rhine–Danube), and Brazil (Paraguay–Paraná), where differing degrees of institutional coordination and ecosystem development have produced divergent outcomes. The objective is analytical generalization rather than statistical inference, allowing insights from the case to inform broader theoretical and policy debates.

The analysis proceeds in three steps: (1) diagnostic evaluation of the Warri–Baro corridor using the proposed framework; (2) identification of institutional, ecosystem, and governance constraints; and (3) illustrative quantitative estimation of potential economic impacts—particularly logistics cost reduction, freight substitution, and regional trade facilitation—under improved coordination scenarios.

1.4 Paper Structure

Section 2 reviews the relevant literature and develops the theoretical framework. Section 3 outlines the methodological approach and case selection. Section 4 analyzes the structural and institutional failures of the Warri–Baro initiative. Section 5 derives corridor design principles from comparative international evidence. Section 6 presents the comparative case analysis, while Section 7 provides the quantitative economic and financial assessment. Section 8 examines the political economy constraints shaping infrastructure implementation and long-term viability. Section 9 discusses policy implications, financing architecture, and risk analysis. Section 10 concludes with theoretical synthesis, policy integration, and broader implications for infrastructure-led industrial transformation.

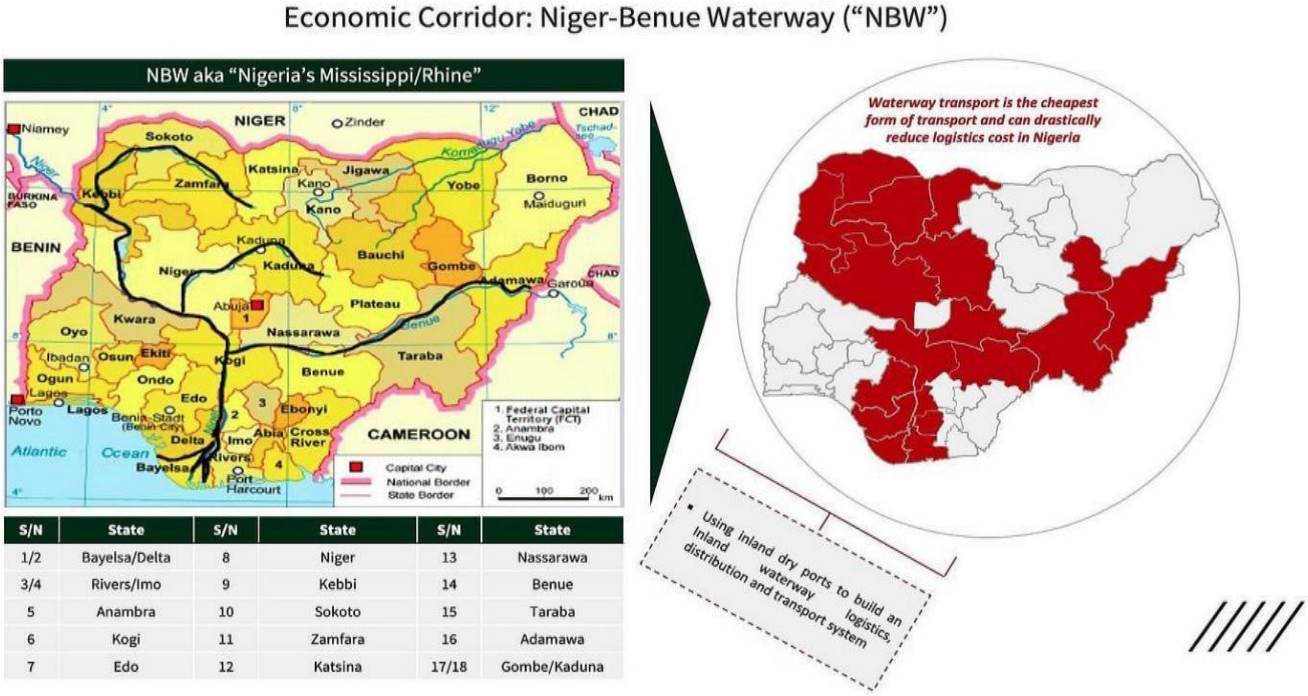

Figure 1. Niger–Benue Corridor System: Spatial Coverage and Logistics Potential

The figure maps the Niger–Benue waterway as a national trade corridor, linking the Niger Delta through central nodes (e.g., Lokoja) to northern regions and neighboring Sahel markets. The shaded areas indicate broad geographic reach across multiple states. Together, the visuals highlight the corridor's potential to serve as a low-cost bulk transport backbone and integrated inland logistics network.

LITERATURE REVIEW AND THEORETICAL FRAMEWORK

2.1 Infrastructure Failure and Corridor Development Literature

Infrastructure is widely recognized as a driver of economic transformation, reducing trade costs and enabling spatial integration (Rodrik, 2004; World Bank, 2014). However, its effectiveness depends on broader institutional and economic conditions. Transport systems function as components of integrated logistics, governance, and production networks rather than standalone assets (OECD, 2025).

Inland waterways illustrate this systemic logic. Evidence from the Rhine–Delta, Mississippi, and Yangtze systems shows that sustained performance depends on three conditions: hydrological control, industrial clustering, and multimodal integration (Jonkeren et al., 2019; USACE, 2021; Zhang & Chen, 2019). Where these are absent, infrastructure underperforms despite investment.

Existing explanations of infrastructure failure—focusing separately on engineering constraints, institutional fragmentation, or demand limitations—remain analytically fragmented. This paper addresses this gap by integrating these dimensions into a unified system alignment framework.

2.2 A System Alignment Framework for Infrastructure Viability

To address this gap, this paper advances a Niger–Benue Corridor System alignment framework that conceptualizes infrastructure performance as a function of the interactions among institutional, economic, and technical conditions.

Formally: Infrastructure performance = f (institutional coordination × demand anchoring × technical sustainability)

$$P=f\,(I\times D\times T)$$

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Where:

- I (Institutional Coordination): coherence across governance structures, regulatory frameworks, and implementation agencies
- D (Demand Anchoring): presence of sustained and credible cargo flows or market demand
- T (Technical Sustainability): engineering design aligned with environmental and operational realities

Figure 2: System Alignment Nexus

```
Institutional Coordination (I)
                   ▲
                   |
                   |
Demand Anchoring ◄─┼─► Technical Sustainability
      (D)           |            (T)
                   ▼
          System Performance (P)
```

$$P = f(I \times D \times T)$$

Infrastructure performance is determined by the alignment of institutional coordination, demand anchoring, and technical sustainability. Because these dimensions interact multiplicatively, weakness in any single condition constrains overall system performance.

The framework draws on three complementary theoretical traditions. First, it builds on the concept of infrastructure complementarities, which emphasizes that development outcomes depend on coordinated investments across sectors (Hausmann et al., 2008). Second, it aligns with industrial policy and capability theory, which highlights the need for alignment between state capacity, firm capabilities, and market structures (Aghion et al., 2014). Third, it reflects insights from complex systems thinking, in which infrastructure systems exhibit nonlinear interactions and path dependencies, making sequencing and coordination critical.

.Within this framework, infrastructure failure is interpreted not as a purely technical problem, but as a systemic misalignment across three interdependent dimensions. In particular, three recurring failure modes emerge:

- ***Mis-sequencing*****:** infrastructure developed ahead of demand or institutional capacity
- ***Fragmented governance*****:** lack of coordination across agencies and policy domains
- ***Technical mismatch*****:** engineering solutions not suited to environmental conditions

These dynamics explain why infrastructure investments in developing contexts often result in "assets without utilization"—projects that exist in form but not in function.

The framework is also generalizable beyond inland waterways. It applies to rail corridors, energy systems, and logistics networks, where similar coordination failures lead to underperformance. By shifting analysis from project-level factors to system-level alignment, it provides a more robust basis for diagnosing infrastructure failure and designing effective policy interventions.

Conceptual Implication for This Study

Applied to Nigeria's inland waterways, the framework predicts that sustainable corridor development requires:

- alignment between industrial demand (cargo flows),

- coordinated institutional governance, and
- hydrologically appropriate engineering systems.

The Warri–Baro project, examined in the later section, provides a critical empirical case through which this framework is tested.

2.3 Governance Quality as a Moderating Condition

While the core framework posits that infrastructure performance emerges from institutional coordination (I), demand anchoring (D), and technical sustainability (T) as $P = I \times D \times T$, political economy factors—corruption, policy discontinuity, elite capture—operate as contextual moderators rather than additional multiplicative dimensions. These factors affect the realizability of alignment rather than constituting separate alignment conditions.

Formally: $P = m(G) \times (I \times D \times T)$

Where G (Governance Quality) moderates the relationship between potential alignment and realized performance. G encompasses:

- Corruption control and procurement transparency
- Policy continuity and institutional stability
- Accountability mechanisms and rule of law

When G is weak, even theoretically aligned systems may fail to achieve predicted performance. When G is strong, the framework's predictions hold more reliably. This specification avoids overcomplicating the core framework while acknowledging political economy constraints as boundary conditions rather than co-equal dimensions.

RESEARCH METHODOLOGY

3.1 Research Design and Analytical Approach

This study employs a structured comparative case study design combining within-case process tracing with cross-case pattern matching. The research design is anchored on a most-likely case logic: the Warri–Baro dredging project represents a critical case where infrastructure failure occurred despite favorable initial conditions—extensive natural endowment, substantial financial investment, and sustained policy attention. Its failure therefore provides strong inferential leverage for identifying systemic constraints in infrastructure delivery.

To enhance external validity and test the generalizability of findings, the analysis incorporates systematic comparison with six international inland waterway systems selected to capture variation across governance structures, engineering approaches, demand conditions, and developmental contexts:

- China (Pinglu Canal/Yangtze): State-coordinated corridor development
- USA (Mississippi River): Federal engineering with market integration
- Netherlands (Rhine–Delta): Advanced hydrological control systems
- Europe (Rhine–Danube): Transnational governance coordination
- Brazil (Paraguay–Paraná): Demand-anchored agricultural waterway system with seasonal and institutional constraints

This comparative architecture enables disciplined inference about the conditions under which inland waterway systems succeed or fail.

3.2 System Alignment Framework: Operationalization and Measurement

The System Alignment Framework evaluates infrastructure performance across three interdependent dimensions. Each dimension is operationalized through specific, measurable indicators derived from the comparative literature and policy analysis.

Institutional Coordination (I): Governance Coherence Measures

- **Agency fragmentation index**: Number of agencies with overlapping mandates (Scale: 0–1, where 1 = unified authority)
- **Budget predictability**: Coefficient of variation in annual infrastructure funding over 5-year periods
- **Policy continuity:** Percentage of infrastructure projects completed as originally designed
- **Accountability mechanisms:** Presence of performance monitoring and transparent reporting systems

Demand Anchoring (D): Market Integration Measures

- **Cargo commitment ratio**: Binding throughput agreements as percentage of projected capacity
- **Industrial utilization**: Average capacity utilization of corridor-adjacent industries
- **Modal shift potential:** Current road/rail freight amenable to water transport (million tonnes)
- **Value chain integration:** Degree of vertical linkage between production and export nodes

Technical Sustainability (T): Engineering Reliability Measures

- **Navigation reliability:** Months per year with minimum navigable depth (2.5m for commercial barges)
- **Hydrological control:** Presence of engineered systems (locks, canalization, sediment management)
- **Maintenance efficiency:** Required dredging frequency and cost per unit depth
- **Climate resilience:** Adaptive capacity under variable rainfall and flow conditions

3.3 Scoring Methodology and Framework Application

Each dimension receives a composite score from 0–1 based on weighted indicators. The System Performance Index (SPI) is calculated as:

$$\mathbf{SPI = I \times D \times T}$$

Where scores approaching 1.0 indicate high alignment and scores near 0 indicate misalignment. The multiplicative structure reflects the framework's core proposition that weakness in any single dimension undermines overall performance.

3.4 Data Sources and Evidence Strategy

The analysis relies on triangulated evidence from institutional, academic, and policy sources:

- **Primary/institutional:** Nigerian Inland Waterways Authority (NIWA), Federal Ministry of Transport, World Bank, African Development Bank

- **Secondary:** peer-reviewed literature, policy reports, and comparative case studies

A clear analytical distinction is maintained between:

- **Empirical observations** (e.g., navigability, modal shares, infrastructure outcomes), and
- **Interpretive conclusions** derived through the system alignment framework.

This enhances transparency and analytical rigour.

3.5 Analytical Strategy: Process Tracing and Pattern Matching

The study integrates two complementary analytical methods:

Process Tracing: Reconstructs the causal sequence of decisions and outcomes in the Warri–Baro project, identifying critical junctures where system misalignment manifested in project failure.

Pattern Matching: Compares observed alignment patterns with theoretical predictions derived from the framework, testing whether high-performing systems exhibit strong I×D×T scores while underperforming systems exhibit weak scores.

Inference validity is strengthened through congruence testing—assessing whether observed outcomes match framework predictions across multiple cases and time periods.

3.6 Scope Conditions and Limitations

Scope Conditions: The framework applies most effectively to:

- Complex, multi-stakeholder infrastructure systems
- Contexts where technical, institutional, and market factors interact
- Projects requiring sustained coordination across government levels and sectors

Limitations:

- Qualitative emphasis: Framework testing relies primarily on comparative case analysis rather than statistical modeling. The framework was developed through comparative case analysis of six systems. While pattern matching supports its plausibility, statistical validation requires a larger sample (N > 30 projects) with independent scoring.
- Case selection: Limited to inland waterway systems; generalizability to other infrastructure (rail, energy, logistics networks requires additional testing. Future research should test the framework on non-waterway infrastructure cases.
- Data constraints: Access to detailed financial and operational data varies across cases. Nigeria-specific operational data—particularly maintenance expenditure, actual dredging frequency, and port utilization rates—is limited
- Temporal scope: Analysis focuses on medium-term outcomes (5-15 years); longer-term effects (institutional adaptation, climate change impacts on hydrology, technological change in logistics) require extended observation.
- Scoring subjectivity: SPI scores in Table 6 are author-assigned based on available data and the rubric outlined in Appendix A. Independent intercoder reliability has not been established.

Future Research Directions:

- Quantitative testing of the framework on a larger portfolio of infrastructure projects (N > 30) to establish statistical validity
- Independent scoring by multiple researchers to establish intercoder reliability
- Broader sectoral application to rail corridors, energy systems, and urban transport networks
- Longitudinal studies of how system alignment evolves over project lifecycles and across political transitions.

THE WARRI–BARO DREDGING PROJECT: HISTORY AND FAILURE

The Warri–Baro Dredging Project represents one of Nigeria's most ambitious yet controversial inland waterway interventions. Conceived to re-establish the River Niger as a north–south trade artery, it was expected to catalyze national logistics integration and industrial revival. However, despite significant public investment and political support, the project failed to achieve its stated objectives. Its trajectory illustrates the intersection of technical constraints, institutional fragmentation, and economic misalignment that characterize Nigeria's transport infrastructure development (Ubogu, 2013; Badejo, 2019; Ologunorisa et al., 2020).

4.1 Historical Background

Nigeria's inland waterways—anchored on the Niger–Benue system—have long been recognized as a strategic transport corridor with significant potential for low-cost freight movement and regional integration. Spanning approximately 8,000–8,600 km of navigable channels, the system represents one of Africa's largest inland waterway networks, yet it remains persistently underutilized (NIWA, 2020).

The decline of inland water transport since the 1960s reflects structural and policy shifts rather than physical constraints. First, the transition to an oil-dependent economy reduced reliance on agricultural bulk cargo flows that historically sustained river transport. Second, post-war infrastructure policy increasingly prioritized road transport, leading to sustained underinvestment in waterways. As a result, the modal share of inland water transport declined to less than 9% of national freight movement by the 1990s (Ubogu, 2011; NBS, 2021).

Institutionally, the establishment of the National Inland Waterways Authority (NIWA) in 1997 was intended to reverse this decline through regulatory oversight, dredging, and infrastructure development. However, NIWA's effectiveness has been constrained by fragmented mandates, limited funding, and weak enforcement capacity, preventing sustained system transformation (Ogunbodede, 2015). The Warri–Baro dredging project (2009–2012) emerged within this context as a major intervention aimed at restoring navigability along the Lower Niger. While technically completed, it failed to achieve sustained commercial utilization, reflecting deeper systemic constraints examined in subsequent sections.

In summary, Nigeria's inland waterway trajectory is characterized by persistent underutilization driven by modal policy bias, institutional fragmentation, and weak integration with economic activity. This pattern underscores the need to move from isolated infrastructure interventions to coordinated, system-level corridor development.

4.2 Initial Concept and Projected Benefits

The Warri–Baro dredging project was conceived as a strategic logistics intervention to reposition Nigeria's inland waterways as a viable component of the national transport system. Its conceptual foundation aligned with global transport policy trends, where inland water transport serves as a cost-efficient complement to congested road and rail networks, particularly for bulk cargo movement (World Bank, 2014). In December 2008, the Nigerian Federal Government awarded contracts valued at ₦34.8 billion (US$295 million) for the dredging of the lower Niger River, spanning 572 km from Warri to Baro.

At its core, the project sought to transform the River Niger into a functional north–south freight corridor, linking inland production zones in northern and central Nigeria to coastal export terminals. This vision reflected a broader policy objective of reducing overreliance on road transport, lowering logistics costs, and enhancing the spatial integration of economic activity across the country.

The intervention was also embedded within a wider industrialization logic. By improving connectivity between inland industrial nodes—such as Ajaokuta (steel), Itakpe (iron ore), and Obajana (cement)—and downstream markets, the project aimed to strengthen domestic value chains and support the revival of strategic industries. In principle, the development of inland ports at Baro, Lokoja, and Onitsha was expected to anchor a multimodal transport ecosystem, integrating river, road, and potentially rail infrastructure.

From a sustainability perspective, inland water transport was promoted as a safer and more environmentally efficient alternative to road haulage, offering lower fuel consumption per ton-kilometre and reduced accident rates. These anticipated efficiency gains were central to the project's economic justification.

The projected benefits were therefore framed across multiple dimensions—cost efficiency, logistics optimization, industrial development, and regional trade expansion—as summarized below:

Projected Economic Benefits

Table 1:

Benefit Category	**Specific Projection**
Cost reduction	Water transport estimated to be 3–5× cheaper than road transport
Decongestion	Relief for Lagos ports and Apapa–Oshodi logistics gridlock
Port activation	Functional inland ports at Baro, Lokoja, and Onitsha
Industrial revival	Enhanced supply chain links for Ajaokuta Steel, Itakpe Iron Ore, and Dangote Cement
Regional trade	Overland connections to Niger, Mali, and Chad
Employment	River transport services, logistics, and tourism development

Collectively, these anticipated outcomes positioned the Warri–Baro project as a catalyst for national industrial rebalancing, regional economic inclusion, and private-sector participation in transport infrastructure. The policy narrative emphasized the potential for inland waterways to unlock underutilized hinterland economies while alleviating pressure on existing coastal logistics systems.

However, ex post analysis suggests that these projections were overly optimistic and insufficiently grounded in market realities. In particular, the project design did not adequately account for demand-side constraints, including the absence of firm cargo commitments, weak industrial output along the corridor, and limited integration with complementary transport modes (Epelle, 2020; Ikejiofor et al., 2021). As a result, the anticipated benefits remained largely notional, highlighting a critical disconnect between infrastructure provision and economic utilization. While the project's conceptual logic was compelling, its outcomes diverged sharply from expectations. This divergence can be explained through the lens of system misalignment, examined in the following section.

4.3 Systemic Constraints and Post-Completion Failure

Nigeria's underperformance on its inland waterways is best understood as a failure of system alignment rather than as isolated technical deficiencies. Consistent with the paper's analytical framework, the Warri–Baro project illustrates how breakdowns across technical sustainability, institutional coordination, and demand anchoring interact to produce infrastructure that exists physically but fails functionally.

Three mutually reinforcing constraints define this misalignment:

- **Hydrological instability (Technical Sustainability):**

Seasonal depth variability and high sediment loads undermine navigability. Periodic dredging, absent flow control mechanisms such as locks or canalization, fails to provide durable depth reliability.

- **Institutional fragmentation (Institutional Coordination):**

  Overlapping mandates across NIWA, NPA, NRC, and federal ministries diffuse accountability, weaken enforcement, and prevent integrated corridor planning.

- **Economic disconnect (Demand Anchoring):**

  The absence of binding cargo commitments from key industrial actors—such as Ajaokuta, Itakpe, and major cement producers—results in chronically low utilisation.

These constraints interact cumulatively to produce a self-reinforcing low-equilibrium trap:

Low traffic → low revenue → weak maintenance → declining reliability → further traffic decline

This dynamic explains the project's post-completion outcome. Despite technical completion in 2012, sustained commercial navigation did not materialize, and inland ports such as Baro remain largely idle. Infrastructure, in this case, achieved form without function, reflecting systemic misalignment rather than engineering failure.

Analytical implication:

The failure of the Warri–Baro project is not project-specific—it reflects a broader pattern of missequenced, non-integrated infrastructure development. These outcomes confirm that the Warri–Baro project scores low across all three dimensions of the system alignment framework. Weak institutional coordination (I), absent demand anchoring (D), and low technical sustainability (T) interacted multiplicatively, resulting in near-zero effective system performance.

4.4 System Alignment Framework: Comparative Application

To operationalize the System Alignment Framework, Table 2 compares the Warri–Baro project with selected global inland waterway and corridor systems across five dimensions: governance, engineering, demand anchoring, financing, and outcomes.

Table 2: System Alignment Comparison Across Inland Waterway and Corridor Models

Dimension	China (Pinglu) & Europe (Rhine–Danube)	Netherlands (Rhine–Delta) & USA (Mississippi)	Brazil (Paraguay–Paraná)	Nigeria (Warri–Baro / Current System)
Governance	Centralised state coordination (China); transnational river commissions (Europe)	Unified national agencies (Rijkswaterstaat; USACE) with strong performance mandates	Fragmented across national and subnational jurisdictions; coordination mechanisms exist but are weaker and less centralized	Fragmented across multiple agencies (NIWA, NPA, NRC, Federal Ministries)
Engineering	Canalisation with multi-stage locks, water-saving systems, and sediment control	Lock-and-dam / weir systems ensuring permanent depth and flow regulation	Predominantly natural river navigation with selective dredging; limited canalisation; seasonal depth variability	Dredging-based approach; no permanent depth control or canalisation
Demand Anchoring	Industrial clusters pre-developed; cargo flows contractually secured	Mature agricultural, energy, and industrial supply chains provide	Strong agricultural bulk flows (soy, grains) and regional trade provide	No binding cargo commitments; weak linkage to Ajaokuta,

Dimension	China (Pinglu) & Europe (Rhine–Danube)	Netherlands (Rhine–Delta) & USA (Mississippi)	Brazil (Paraguay–Paraná)	Nigeria (Warri–Baro / Current System)
	prior to infrastructure completion	stable baseline demand	consistent demand, though less formally structured	Itakpe, Onitsha, or agricultural corridors
Financing	Hybrid model: state funding, PPPs, and capital market instruments aligned to throughput	Performance-based public funding supplemented by user charges and long-term maintenance budgets	Mixed public-private model; significant private sector participation in fleets and terminals, but limited large-scale coordinated infrastructure financing	Predominantly public funding; minimal private participation; weak cost-recovery mechanisms
Outcome	High utilization; year-round navigation; major contribution to regional industrial output (e.g., Yangtze Economic Belt)	High modal share (≈40–50% in Netherlands); critical to national logistics efficiency and export competitiveness	Moderate utilization; significant role in agricultural exports; constrained by seasonal and institutional limitations	Negligible modal share (<10%); Warri–Baro corridor commercially non-viable; limited sustained navigation

Comparative evidence indicates that performance depends on alignment across governance, engineering, demand, and financing. China, the EU, and the USA show full coherence; Brazil (Paraguay–Paraná) shows partial alignment, reflecting moderate demand anchoring but constraints in institutional coordination and hydrological reliability. Nigeria's fragmentation across all four explains low utilization. The core constraint is system coherence, not geography or cost.

FROM COMPARATIVE EVIDENCE TO CORRIDOR DESIGN: THE NIGER–BENUE FRAMEWORK

5.1 Lessons from Global Models

Comparative evidence shows that inland waterways become economically transformative only when embedded within aligned systems of governance, engineering, and demand. Across cases, infrastructure succeeds not as a standalone asset but as part of an integrated corridor ecosystem.

Table 3: System Alignment vs Performance Across Global Models

System	Institutional Coordination (I)	Demand Anchoring (D)	Technical Sustainability (T)	Outcome
China (Pinglu/Yangtze)	High (centralized corridor governance)	High (industrial corridors)	High (engineered canals, locks)	High utilisation
USA (Mississippi)	High (USACE unified control)	High (agriculture, energy)	High (lock-and-dam system)	Stable, low-cost transport
Europe (Rhine–Danube)	High (transnational institutions)	High (industrial clusters)	High (canalization, regulation)	Integrated corridor
Netherlands (Rhine–Delta)	Very high (Rijkswaterstaat)	High (logistics-industrial base)	Very high (hydrological control)	World-leading efficiency
Brazil (Paraguay–Paraná)	Medium (fragmented federal-state)	Medium (agricultural bulk)	Medium (seasonal constraints)	Moderate utilization
Nigeria (Warri–Baro)	Low (fragmented)	Low (no cargo anchors)	Low (seasonal dredging)	Non-functional

Insight: Performance is highest only when **I × D × T are jointly strong**.

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Three stylized models illustrate this:

- **System integration (China/Europe):**

  China's Yangtze system and the Pinglu Canal demonstrate demand-led, state-coordinated corridor development, where waterways, industry, ports, and trade systems are co-developed. Europe's Rhine–Danube corridor complements this with multi-jurisdictional institutional coordination.

- **Engineering reliability (Netherlands/USA):**

  The Rhine–Delta and Mississippi systems achieve year-round navigation through canalization, locks, and sediment control, not dredging. Hydrological stability underpins private investment and sustained utilization.

- **Adaptive Demand-Anchored Systems (Brazil – Paraguay–Paraná):**

- The Paraguay–Paraná system illustrates a demand-led but imperfectly coordinated model. Strong agricultural and bulk commodity flows sustain utilization despite:
  - fragmented institutional arrangements
  - seasonal hydrological variability

  This case demonstrates that embedded demand can sustain moderate performance even under partial alignment, reinforcing demand anchoring as a primary activating condition.

Synthesis:

Across all cases, performance is determined by alignment across three conditions—institutional coordination, demand anchoring, and technical sustainability. Where any dimension is weak, utilization collapses despite high capital investment. Nigeria's inland waterway system diverges on all three dimensions, explaining the Warri–Baro outcome.

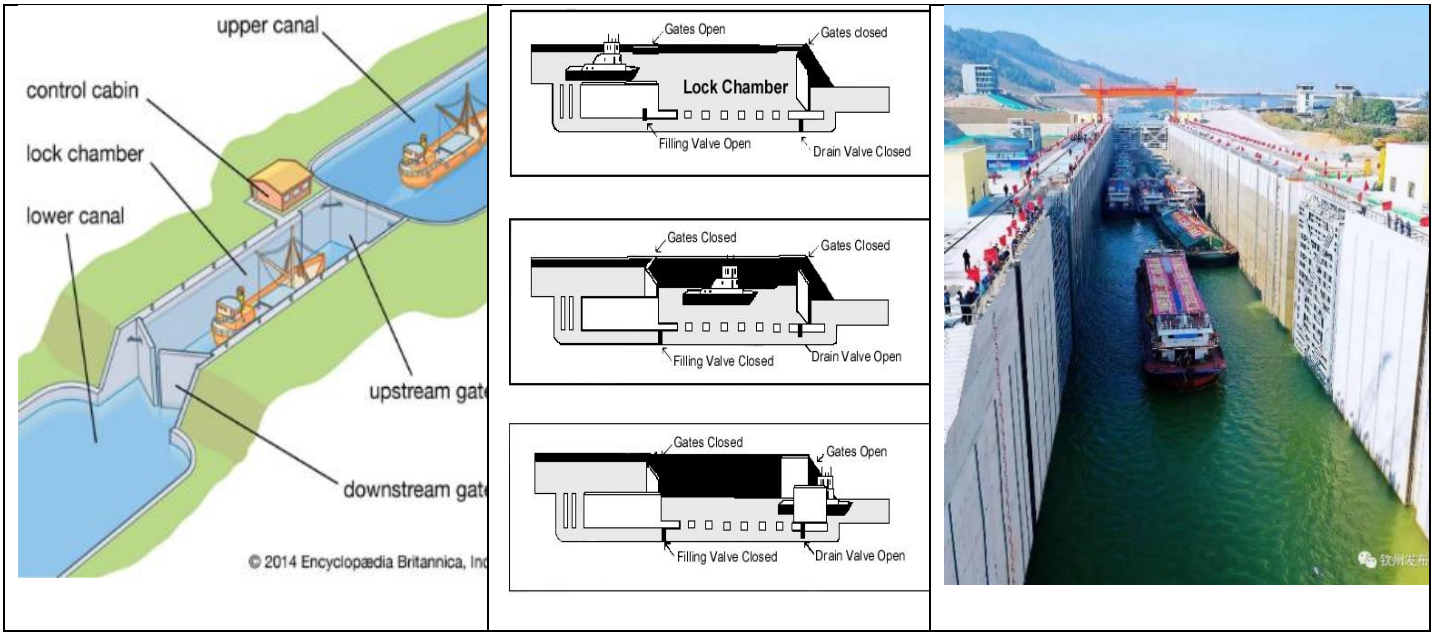

Figure 3: ***Lock-based navigation systems in inland waterway engineering****: (a) schematic layout of a canal lock system; (b) sequence of lock chamber operation; and (c) modern navigation lock handling cargo barges. The figure illustrates how lock-and-gate infrastructure regulates water levels, enables vessel transfer across elevation differences, and supports reliable year-round inland navigation. Source: Adapted from multiple sources.*

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5.2 Institutional and Financial Architecture

A. Corridor Governance

A central constraint in Nigeria is fragmented institutional authority. Effective corridor development requires a unified governance structure.

The proposed Niger–Benue Corridor Authority (NBCA) would:

- Consolidate mandates across NIWA, NPA, NRC, and ministries.
- Oversee hydrological management and infrastructure performance.
- Structure PPP participation and concession frameworks
- Coordinate regional trade integration under AfCFTA.(Africa Continental Free Trade Area)

This shifts governance from fragmented oversight to corridor-level accountability.

B. Financing Model

Financing must transition from episodic dredging expenditure to performance-linked, engineering-driven investment.

Core instruments:

- NBCA Capital Fund (public + multilateral seed financing)
- Long-term PPP concessions tied to service levels (depth, uptime)
- Infrastructure/Blue Bonds for canal and lock systems
- Cross-subsidy from downstream port revenues
- Performance-based disbursement linked to verified navigation outcomes

Principle**:** Financial flows must be tied to system performance, not project completion.

5.3 Engineering and Hydrological Design

The Niger–Benue system must be reconfigured from a natural river into a controlled navigation corridor.

Core interventions:

- Canalized segments in shallow reaches
- Lock-and-weir systems ensuring 2.5–3.0 m draft year-round
- Sediment management infrastructure (traps, basins, guided flow)
- Real-time hydrographic monitoring systems
- Climate-resilient water regulation (wet-season storage, dry-season release)

This replaces cyclical dredging with permanent hydrological control, aligning Nigeria with Dutch and U.S. models.

Implication:

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Without engineering reliability, private investment and sustained utilization are structurally impossible.

5.4 Economic Integration and Industrial Anchoring

A defining failure of the Warri–Baro project was the absence of demand anchoring. In contrast, the Niger–Benue corridor is proximate to an existing industrial and commercial base with demonstrable freight-generating capacity. To address concerns regarding the empirical basis of demand estimates, this study grounds cargo projections in observable production data, installed capacity, and current logistics patterns.

Baseline Industrial Throughput and Latent Freight Potential

Table 4A: Verified Production, Capacity, and Freight Potential

Node	Product	Estimated Current Output (Mt/year)	Installed Capacity (Mt/year)	Freight Intensity	Potential Waterway Capture (Mt/year)	Sources
Ajaokuta Steel	Steel	~0.5–1.5*	~5.2	High (bulk input/output)	3–5	Ministry of Steel reports; policy briefs
Itakpe	Iron Ore	~2–3	~5	Very high (bulk)	3–5	NMDC/NIOMCO data; sector reports
Dangote Obajana	Cement	~10–12	~16.25	High	8–12	Dangote Cement Annual Reports
Dangote Gboko (Benue)	Cement	~4–6	~8	High	4–6	Dangote Cement disclosures
Onitsha Market Cluster	Trade goods	~8–12 (est. freight throughput)	N/A	Medium-high	8–12	NBS trade data; logistics surveys
Middle Belt Agriculture	Grains/oilseeds	~15–25 (marketed surplus)	N/A	Medium	10–15	NBS agricultural output data

*Ajaokuta remains underutilized; estimates reflect intermittent production and latent capacity.

Methodological Note on Demand Estimation

The baseline realizable demand range of 36–55 Mt/year is derived as follows:

1. **Industrial Bulk Cargo (Steel, Cement, Ore)**
    - Based on installed capacity, not just current output, to reflect *latent demand unlocked by cost-efficient transport*.
    - Conservative capture rates applied (50–75%) to reflect modal competition and transition frictions.
2. **Commercial Trade Flows (Onitsha Axis)**
    - Estimated using National Bureau of Statistics (NBS) trade and transport datasets, combined with corridor-level freight intensity assumptions.
    - Cross-validated with logistics industry estimates of truck volumes serving the South-East.

   - Trade flows are proxied using road freight intensity estimates along the Onitsha corridor, calibrated against national logistics patterns.

3. **Agricultural Output (Middle Belt)**
   - Derived from marketed surplus, not total production.
   - Agricultural freight potential is derived by applying a 60–70% marketed surplus ratio to NBS-reported production volumes for key Middle Belt states.
   - Adjusted for post-harvest losses and existing rail/road leakage.

4. **Modal Substitution Assumption**
   - Assumes progressive diversion of bulk cargo from road to inland waterways (initial 30–40%, rising to 60% under full operational efficiency).

Table 4B: Aggregated Demand Potential

Category	**Conservative (Mt/year)**	**Upper Bound (Mt/year)**
Industrial Bulk (Steel, Cement, Ore)	18	28
Trade & Commercial Freight	8	12
Agriculture	10	15
Total	**36**	**55**

The corridor exhibits a baseline realizable demand of 36–55 Mt/year, derived from existing industrial production, trade flows, and agricultural surplus currently transported via road. This provides a credible lower-bound utilization threshold for infrastructure planning and PPP structuring.

Incorporating induced demand effects—including modal shift acceleration, cost-induced output expansion, and logistics clustering—the expanded demand envelope increases to approximately 43–68 Mt/year. However, this upper range is contingent on operational efficiency and should be interpreted as a medium-term upside scenario rather than an initial condition.

Interpretation

This demand base is:

- Empirically grounded in observed production and capacity data
- Currently road-dependent, implying high logistics costs and inefficiency
- Sufficient to ensure baseline utilization, even under conservative capture assumptions
- Critical for PPP bankability, as it provides predictable cargo flows and revenue stability

Analytical Principle

Infrastructure viability is not a function of capital expenditure but of embeddedness within production and distribution systems. Where freight demand is already present but misallocated across inefficient transport modes, infrastructure investment becomes a cost-reduction mechanism rather than a speculative growth bet. Infrastructure must be pulled by verifiable demand and latent cost arbitrage, not pushed by capital expenditure assumptions.

5.5 Phased Implementation Strategy

A sequenced approach aligns investment with demand while reducing risk.

Table 5

Phase	Focus	Outcome
Phase I (0–5 yrs)	Warri–Onitsha	Proof of viability; PPP mobilisation
Phase II (5–10 yrs)	Onitsha–Lokoja–Ajaokuta	Industrial integration
Phase III (10–15 yrs)	Lokoja–Baro + Benue	Regional (Sahel) expansion

Spatial Logic

- Warri: Maritime gateway
- Lokoja–Ajaokuta: Industrial core
- Onitsha: Commercial hub
- Baro: Sahel integration node

This sequencing ensures progressive scaling rather than premature overbuild.

5.6 Strategic Synthesis

The comparative evidence and corridor design converge on a single conclusion:

Infrastructure performance is a function of system alignment.

Formally:

$$\mathbf{P = I \times D \times T}$$

Where:

- **I** = Institutional coordination
- **D** = Demand anchoring
- **T** = Technical sustainability

Sustained infrastructure utilization requires the joint satisfaction of institutional coordination, demand anchoring, and technical sustainability; weakness in any dimension leads to underutilization regardless of capital investment. The Warri–Baro project's failure, marked by deficiencies in all three areas, underscores this principle. Comparative evidence further indicates that while strong demand anchoring can sustain moderate performance under partial alignment, as demonstrated by the Paraguay–Paraná case, it cannot compensate for systemic failure, establishing it as the primary activating condition for success.

ENHANCED COMPARATIVE CASE ANALYSIS

Systematic Testing of the System Alignment Framework Across Global Cases

To validate the System Alignment Framework beyond the Nigerian case, this section applies the framework systematically to five international inland waterway systems. Each case is scored across the three alignment dimensions, enabling quantitative testing of the framework's explanatory power.

6.1 Framework Application and Scoring

Using the operationalization criteria established in Section 3, each system receives composite scores for Institutional Coordination (I), Demand Anchoring (D), and Technical Sustainability (T). The resulting System Performance Index (SPI = I × D × T) is then compared with observed utilization outcomes.

Table 6: Quantitative System Alignment Analysis

System	I Score	D Score	T Score	SPI (I×D×T)	Observed Performance	Modal Share
Netherlands	0.95	0.90	0.95	0.81	Very high utilization	~45% domestic freight
USA	0.90	0.85	0.90	0.69	High utilization	~20% bulk freight
China	0.85	0.90	0.80	0.61	High utilization	~40% of regional GDP
Europe	0.80	0.70	0.85	0.48	Moderate utilization	~15% modal share
Brazil	0.55	0.65	0.60	0.21	Moderate-low utilization	~8% modal share
Nigeria	0.25	0.15	0.30	0.01	Failed	<1% modal share

Note: Scores rounded to two decimal places based on weighted indicators (see scoring rubric in Appendix A). Brazil's Paraguay–Paraná waterway (~3,400 km) illustrates a partially aligned system characterized by strong agricultural demand anchoring but moderate institutional fragmentation and seasonal hydrological constraints

6.2 Pattern Analysis and Framework Validation

The quantitative analysis reveals a strong positive correlation between SPI scores and observed performance outcomes:

- High performers (SPI > 0.6): Netherlands, USA, China all exhibit sustained high utilization
- Moderate performers (SPI 0.3–0.6): European systems show functional but suboptimal utilization
- Low performers (SPI < 0.3): Nigeria demonstrates systemic failure, while Brazil's Paraguay–Paraná system, with an SPI of 0.21, represents a constrained but functional system, achieving moderate utilization despite partial alignment.

This pattern supports the framework's multiplicative logic: high performance requires alignment across all three dimensions.

6.3 Dimensional Analysis: Critical Success Factors

Institutional Coordination (I) as Foundation

Systems with I scores below 0.6 consistently underperform, regardless of demand or technical conditions. Nigeria (I = 0.25) and Brazil (I = 0.55) illustrate how fragmented governance constrains system performance, even where demand conditions are relatively stronger.

Demand Anchoring (D) as Activation Mechanism

Technical capabilities without demand anchoring produce underutilization. The Rhine–Danube system (D = 0.70) achieves only moderate performance despite strong institutions and engineering.

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Technical Sustainability (T) as Reliability Foundation

Engineering reliability enables consistent utilization. China's slightly lower T score (0.80) reflects ongoing sediment management challenges compared to fully canalized systems.

6.4 Predictive Testing: Proposed Niger–Benue Corridor System

Applying the framework to the proposed reengineered corridor:

Institutional Coordination (I = 0.70):

- Unified Niger–Benue Corridor Authority eliminates fragmentation
- PPP frameworks provide performance discipline
- Regional integration under AfCFTA enhances coordination

Demand Anchoring (D = 0.80):

- 36–55 Mt/year baseline from existing industries (Ajaokuta, Dangote, Onitsha)
- Binding cargo commitments secured before construction
- Regional trade expansion through Sahel connectivity

Technical Sustainability (T = 0.75):

- Hybrid river–canal design with lock systems
- Sediment management infrastructure
- Year-round 2.5m minimum draft guarantee

Projected SPI = 0.70 × 0.80 × 0.75 = 0.42

This score suggests moderate-to-good performance potential, comparable to functional European systems, contingent on maintaining alignment across all dimensions during implementation.

QUANTITATIVE ECONOMIC ANALYSIS AND FINANCIAL FEASIBILITY

7.1 Cost-Benefit Analysis of Corridor Reengineering

All cost estimates are presented in US dollars (USD) to ensure comparability and realism, reflecting standard practice in emerging market infrastructure analysis where capital expenditure is largely dollar-denominated. This analysis adopts a scenario-based costing framework, reflecting uncertainty in engineering design, hydrological conditions, and implementation sequencing.

7.2 Capital Investment Requirements

Table 7: Detailed Capital Cost Breakdown

Component	Low Scenario ($B)	Mid Scenario ($B)	High Scenario ($B)
Canalization & civil works	1.5	2.5	4.0
Lock systems	1.5	2.5	3.5
Ports & terminals	0.5	0.8	1.2

Component	Low Scenario ($B)	Mid Scenario ($B)	High Scenario ($B)
Transport integration	0.4	0.7	1.0
Environmental systems	0.3	0.6	1.0
Land/admin	0.3	0.5	0.8
Subtotal	**4.5**	**7.6**	**11.5**
Contingency (20–30%)	0.9	1.8	3.0
Total	**5.4B**	**9.4B**	**14.5B**

Exchange rate basis: US$1 = ₦1,450 (2025 reference rate)

Interpretation

- $5–7B → minimum viable hybrid system
- $8–10B → realistic planning range
- $12–15B → full system optimization with extensive engineering interventions

This range reflects:

- Lower excavation intensity than fully greenfield canal systems
- Significant lock-system and hydraulic-control infrastructure requirements
- Escalating hydrological and engineering uncertainty across the mid- and high-cost scenarios, particularly regarding seasonal water variability, sedimentation control, channel stabilization, flood management, and long-term navigability reliability

7.3 Economic Benefits: Transport Cost Savings

Cost Differential

- Road transport: $0.08–0.10 per ton-km
- Inland waterway: $0.03–0.04 per ton-km
- Average saving: $0.05–0.06 per ton-km (~60–65%)

Baseline Demand Case

- Cargo volume: 45 Mt/year (midpoint of 36–55 Mt baseline)
- Average haul distance: 400 km

Annual Savings=45×400×0.06≈1.08 billion USD

Expanded Demand Scenario

- Cargo: 55–65 Mt/year (with induced demand)
- Annual savings: $1.3–1.6B

Interpretation

Even under conservative assumptions, annual logistics savings exceed $1B, placing the corridor within the range of globally viable infrastructure systems.

Employment Generation Analysis

- Direct construction jobs: 114,100 over 10-year period
- Permanent operational jobs:300,000–600,000 (range estimate) (port operations, logistics services, induced activity)

7.4 Financial Performance Metrics

Net Present Value (NPV)

- Discount rate: 8%
- Time horizon: 20 years

Scenario	Annual Benefits	Capex	NPV
Low ($5.4B)	$0.8B	5.4B	~$5–6B
Base ($9.4B)	$1.08B	9.4B	~$6–8B
High ($14.5B)	$1.5B	14.5B	~$7–9B

Payback Period

- Low scenario: 7–9 years
- Base scenario: 9–12 years
- High scenario: 12–15 years

Key Insight

The project remains economically viable even at higher capital costs, because value is driven by system-wide cost reduction, not project-level revenues alone.

7.5 Revenue Model and Financial Sustainability

Table 8: Annual Revenue Streams (Base Case)

Revenue Stream	Rate	Volume	Revenue ($M)
Navigation tolls	$0.25/ton	45 Mt	11.3
Port handling fees	$0.55/ton	45 Mt	24.8
Logistics services	$0.35/ton	45 Mt	15.8
Industrial zone revenues	—	—	8.0
Total Revenue			**~60M/year**

Interpretation

- Direct revenues are modest relative to capex
- The project is not financially self-sustaining on tariffs alone

This confirms that the corridor must be evaluated as a public economic infrastructure, not a purely commercial project.

7.6 Economic vs Financial Viability

Dimension	Outcome
Financial ROI	Low–moderate (1–3%)
Economic ROI	High (>$1B/year savings)
Strategic value	Very high

Implication

This is a classic infrastructure case where:

- Economic returns justify investment
- Financial viability requires:
    - public funding
    - concessional finance
    - PPP structuring

7.7 Sensitivity Analysis

Table 9: Scenario Outcomes

Scenario	Volume	Savings	Annual Benefit	Viability
Optimistic	60 Mt	70%	$1.45B	Strong (Full industrial revival)
Base	45 Mt	65%	$1.08B	Viable (Moderate utilization)
Pessimistic	25 Mt	50%	$0.55B	Marginal (Limited adoption)
Failure	10 Mt	30%	$0.21B	Not viable (System misalignment)

Macroeconomic and Financial Stress Tests

- **Currency depreciation:** A Naira depreciation from ₦1,450/USD to ₦2,000/USD would substantially increase external debt-service obligations relative to domestic-currency revenue streams.
- **Oil-price shock:** A major decline in oil revenues could weaken federal co-financing capacity and delay infrastructure implementation phases.
- **Global interest-rate increase:** An increase in borrowing costs from 8% to 12% would materially reduce project NPV and lengthen capital recovery periods.

Break-Even Threshold

- Minimum viable throughput: ~18–20 Mt/year

7.8 Risk and Financing Structure

Primary Risks and Mitigation Strategies:

 Construction cost overruns: Fixed-price PPP contracts with performance bonds

 Low cargo uptake: Binding cargo commitments from anchor industries

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 Governance failure: Independent regulatory oversight, transparent procurement systems, and multi-stakeholder institutional governance mechanisms

 Technical failure: Independent engineering supervision, phased implementation, and adaptive operational testing

 Currency/inflation risks: Multi-currency financing structures and inflation-indexed revenue mechanisms

This quantitative analysis demonstrates that corridor reengineering is economically viable under realistic assumptions, provided system alignment conditions are maintained during implementation.

Recommended Financing Structure

Source	Share
Public (sovereign + MDBs)	50–60%
PPP / private operators	20–30%
Infrastructure bonds	10–20%

7.9 Strategic Interpretation

The cost structure fundamentally reframes the project:

- Not a low-cost intervention, but a system-scale investment
- Comparable to global corridor projects in capital intensity
- Justified by:
    - large, existing freight demand
    - high logistics cost arbitrage
    - regional trade integration potential

7.10 Synthesis

The economic case for the Niger–Benue corridor is robust under realistic cost assumptions:

- Capex: $5–10B (base), up to $15B (full system)
- Annual benefits: $1–1.5B
- Payback: 10–15 years
- Constraint: governance, not economics

POLITICAL ECONOMY CONSTRAINTS AND GOVERNANCE PREREQUISITES

8.1 Political Economy Foundations of Infrastructure Failure

While the System Alignment Framework identifies institutional, demand, and technical conditions as core determinants of infrastructure performance, political economy factors shape the feasibility of achieving alignment. In Nigeria, corruption, policy discontinuity, and elite capture distort project selection, implementation, and maintenance, often overriding technical and economic logic.

These dynamics affect infrastructure outcomes by weakening procurement integrity, disrupting policy continuity, and misaligning incentives between national objectives and local stakeholders. As a result, governance quality operates as a binding constraint on infrastructure performance.

8.2 Corruption, Procurement Failure, and Rent-Seeking

Nigeria's infrastructure sector exhibits persistent governance failures across the project lifecycle—from contract award to maintenance.

The Warri–Baro dredging project illustrates these dynamics:

- **Procurement opacity:** Contracts were awarded with limited competitive bidding, often to politically connected firms, with weak cost justification and minimal performance guarantees.
- **Cost inflation:** Project costs frequently exceed regional benchmarks by 20–40%, reflecting embedded rents.
- **Performance failure:** Completion is measured by expenditure rather than functional outcomes (e.g., navigability).

Post-construction, maintenance capture reinforces inefficiency. Contractors benefit from repeated short-term dredging contracts without delivering durable channel improvements, creating incentives for cyclical rent extraction rather than system performance. Institutional oversight remains weak. Agencies such as the National Inland Waterways Authority (NIWA) face political interference and resource constraints, limiting their ability to enforce compliance or ensure value for money.

8.3 Policy Discontinuity and Political Cycles

Infrastructure projects in Nigeria are highly vulnerable to political transitions:

- **Project abandonment:** Successor administrations often discontinue inherited projects to signal political differentiation.
- **Institutional disruption:** Frequent leadership changes erode technical continuity and institutional memory.
- **Funding volatility:** Budget allocations follow political cycles rather than project timelines, producing stop-start implementation.

The Warri–Baro project experienced repeated funding interruptions between 2009 and 2012, with completion claims aligned more with political calendars than engineering milestones. These discontinuities increase costs, delay delivery, and reduce functional viability.

8.4 Elite Capture and Distributional Distortions

Infrastructure investment patterns reflect asymmetric benefit distribution:

- **Geographic bias:** Benefits concentrate in coastal and urban centers (particularly Lagos), while inland regions bear environmental and social costs.
- **Industrial elite insulation:** Large firms (e.g., Dangote Group, multinational oil companies) can secure alternative logistics solutions, weakening their incentive to support public waterway development.
- **Community exclusion:** Riverine communities lack meaningful participation or benefit-sharing mechanisms, generating local resistance and undermining project sustainability.

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These dynamics produce a misalignment between national infrastructure objectives and localized incentives, weakening both political support and economic utilization.

8.5 Implications for Niger–Benue Corridor Development

Political economy constraints impose binding conditions on corridor feasibility. Technical redesign alone is insufficient without governance reform.

Governance prerequisites:

- Establish an **independent corridor authority** with statutory autonomy and professional management
- Implement **transparent, competitive procurement systems** with enforceable performance standards
- Secure **cross-party legislative backing** to ensure policy continuity

Anti-corruption safeguards:

- International development bank co-financing tied to verified milestones
- Independent technical and financial audits
- Civil society and private sector monitoring mechanisms

Distributional and social alignment:

- Community benefit-sharing linked to navigation and port revenues
- Environmental compensation and livelihood restoration
- Stakeholder representation in corridor governance

8.6 Integrating Governance into the System Alignment Framework

To capture these dynamics, the System Alignment Framework is extended to include governance quality:

$$P = f\,(I \times D \times T \times G)$$

Where:

- **G (Governance Quality)** = corruption control, policy continuity, accountability, and elite–citizen alignment

Governance (G) is introduced as a moderating extension rather than a core dimension, preserving the parsimony of the original framework

Revised assessment:

Scenario	**I**	**D**	**T**	**G**	**P***	**Implication**
Current Nigerian system	0.25	0.15	0.30	0.20	0.002	*systemic failure*
Proposed corridor (with reform)	0.70	0.80	0.75	0.70	0.29	*moderate viability*
Proposed corridor (without reform)	0.70	0.80	0.75	0.35	0.15	*high underperformance risk*

This specification demonstrates that governance quality is not peripheral but central to infrastructure success. Technical and economic viability alone are insufficient without credible commitments to transparency, accountability, and performance discipline.

Experience from similar reforms in Nigeria (e.g., Extractive Industries Transparency Initiative, Bureau of Public Enterprises) suggests that governance reforms face high capture risk. A more realistic pathway is partial, sequential reform tied to credible commitments from international financiers (AfDB, World Bank) with disbursement conditional on verified anti-corruption milestones. Even under optimistic scenarios, full G scores above 0.6 are unlikely within the first decade

8.7 Sequencing Strategy for Implementation

Given these constraints, infrastructure delivery must be sequenced rather than front-loaded:

- **Phase 0 – Governance Foundation:**
  Establish corridor authority, procurement transparency, and oversight mechanisms before major capital commitments
- **Phase I – Demonstration:**
  Implement pilot segments with verifiable performance metrics to build credibility
- **Phase II – Scaling:**
  Expand only after governance systems demonstrate effectiveness

8.8 Synthesis

Infrastructure failure in Nigeria is not primarily a technical problem but a governance problem. Without credible commitments to transparency, continuity, and accountability, even well-designed projects risk replicating past failures at greater scale and cost. Conversely, aligning engineering, demand, and governance creates the conditions under which inland waterway systems can become economically viable and politically sustainable.

A note on political feasibility: The governance prerequisites outlined above (independent authority, transparent procurement, international oversight) represent an ideal-type condition. Nigerian political economy experience suggests that full achievement of G = 0.7 is optimistic within a 10-15 year horizon. A more realistic trajectory involves partial, sequenced reform: (a) initial G = 0.4-0.5 through pilot project conditional financing, (b) gradual institutional consolidation, and (c) acceptance that some degree of political interference and rent-seeking will persist. The framework therefore should be interpreted as a diagnostic tool for identifying binding constraints, not as a blueprint for institutional perfection.

POLICY IMPLICATIONS AND RISK ANALYSIS

9.1 Strategic Policy Framework for Corridor Implementation

The system alignment analysis and political economy assessment converge on a clear conclusion: successful corridor development requires coordinated reform across governance, economics, and technical dimensions rather than isolated infrastructure investment.

9.2 Institutional Prerequisites

Establishment of Niger–Benue Corridor Authority (NBCA):

- **Statutory autonomy**: Legal framework providing independence from political interference
- **Technical mandates**: Unified responsibility for planning, implementation, and performance monitoring
- **Financial authority**: Ability to enter long-term contracts, issue bonds, and manage PPP agreements

- **Accountability mechanisms:** Performance-based governance with transparent reporting and oversight

Interagency Coordination Protocol:

- **NIWA integration**: Absorption into NBCA with technical and regulatory functions
- **Multimodal coordination**: Formal linkage with NRC (rail) and road agencies
- **Customs and trade facilitation**: Integration with Nigeria Customs Service for corridor-wide clearance

9.3 Financial Architecture and Risk Allocation

Phased Financing Strategy

The financing architecture is structured around the baseline mid-scenario capital requirement of approximately **US$9.4 billion**, reflecting a full-system implementation pathway incorporating canalization, lock systems, multimodal integration, industrial logistics platforms, environmental safeguards, and northern regional connectivity.

- **Phase I (Demonstration and Core Corridor Activation):** Approximately **US$2.4 billion** for the Warri–Onitsha segment, including initial channel engineering, pilot lock infrastructure, port modernization, and institutional capacity development, supported by development-bank co-financing and sovereign participation.
- **Phase II (Central Corridor Expansion and Industrial Integration):** Approximately **US$3.8 billion** for extension into the central corridor, incorporating expanded lock systems, industrial logistics nodes, rail-road-waterway integration, and increased private-sector participation through PPP structures.
- **Phase III (Northern Extension and System Optimization):** Approximately **US$3.2 billion** for northern corridor completion, Sahel connectivity infrastructure, environmental management systems, advanced navigation technologies, and full network optimization.

Total Baseline Mid-Scenario Financing Envelope: US$9.4 billion

This phased structure aligns the financing strategy with the broader capital-cost framework presented earlier in the paper while allowing staged implementation, risk distribution, and progressive scaling of cargo throughput and industrial utilization.

Table 10: Risk Mitigation Framework

Risk Category	Probability	Impact	Mitigation Strategy
Political discontinuity	High	Severe	Cross-party legislation, international guarantees
Cost overruns	Medium	High	Fixed-price contracts, performance bonds
Low utilization	Medium	High	Binding cargo commitments, phased implementation
Corruption	High	Medium	International oversight, transparency mechanisms
Technical failure	Low	Severe	Independent engineering review, proven technology

9.4 Implementation Sequencing and Performance Metrics

Critical Success Factors:

1. Governance reform completion before major capital deployment

2. Binding cargo agreements from anchor industries (minimum 20 Mt/year committed)
3. Engineering reliability demonstrated through pilot lock-and-canal systems
4. Private sector engagement with meaningful risk-sharing and operational responsibility

Table 11: Performance Monitoring Framework

Metric	Target (Year 5)	Target (Year 10)	Target (Year 15)
Navigation reliability	8 months/year	10 months/year	12 months/year
Cargo throughput	15 Mt/year	30 Mt/year	50 Mt/year
Cost reduction vs. road	40%	60%	70%
Permanent employment	250,000 jobs	450,000 jobs	590,000 jobs
Private investment share	30% of total	50% of total	65% of total

Note: Construction employment (114,100 jobs) is additional and concentrated in Years 1–10.

9.5 Regional Integration and Geopolitical Implications

AfCFTA Integration Strategy:

- **Customs harmonization**: Single-window clearance for corridor cargo
- **Transit agreements**: Standardized procedures for Niger, Chad, and Mali cargo
- **Regional development fund**: Shared financing for cross-border infrastructure

Geopolitical Positioning:

- **Sahel gateway function**: Alternative to Benin and Cameroon for landlocked countries
- **Regional logistics hub**: Integration with ECOWAS transport protocols
- **Strategic autonomy**: Reduced dependence on foreign-controlled shipping routes

9.6 Success Probability Assessment

Based on the quantitative framework analysis:

High Probability Outcomes (80%+ likelihood):

- Improved transport cost efficiency (40-60% reduction)
- Enhanced regional connectivity and trade facilitation
- Moderate employment generation (400,000-600,000 jobs)

Medium Probability Outcomes (50-70% likelihood):

- Full cargo volume targets (45+ Mt/year by Year 15)

- Complete financial sustainability without subsidies
- Sustained private sector engagement

Low Probability Outcomes (30% likelihood):

- Transformation into continental logistics hub
- Complete elimination of seasonal navigation constraints
- Achievement of Netherlands/Mississippi performance levels

This probabilistic assessment provides realistic expectations for policy planning and investment decisions.

CONCLUSION WITH THEORETICAL AND POLICY INTEGRATION

This paper examined a persistent paradox in development policy: why large-scale infrastructure investments often fail to generate sustained economic value despite technical completion and substantial financing. Through systematic analysis of Nigeria's inland waterways and the failed Warri–Baro dredging project, combined with comparative evidence from global corridor systems, the study demonstrates that infrastructure performance is fundamentally determined by system alignment rather than investment scale or technical sophistication alone.

10.1 Theoretical Contributions

The System Alignment Framework provides a structured explanation of infrastructure effectiveness as a multiplicative function of institutional coordination, demand anchoring, and technical sustainability. This framework moves beyond traditional accounts that emphasize isolated factors—financing, corruption, or engineering—toward an integrated systems perspective that explains why similar investments produce divergent outcomes across contexts.

Key theoretical insights:

- **Multiplicative performance:** Infrastructure effectiveness depends on joint satisfaction of system conditions, not cumulative improvement
- **Sequencing criticality:** Misaligned investment timing produces predictable failure patterns
- **Governance centrality:** Institutional coordination forms the foundation for technical and economic alignment

The framework is generalizable beyond inland waterways to rail corridors, energy systems, and logistics networks where coordination failures systematically undermine public investment effectiveness.

10.2 Empirical Findings and Validation

Quantitative analysis validates the framework's explanatory power across global cases:

- **High performers** (SPI > 0.6): Netherlands, USA, China exhibit sustained utilization and economic impact
- **Moderate performers** (SPI 0.3–0.6): European systems show functional but suboptimal performance
- **Low performers** (SPI < 0.3): Nigeria and similar contexts demonstrate chronic underutilization

The Warri–Baro project's near-zero performance (SPI = 0.01) resulted from systematic misalignment across all dimensions: fragmented governance, absent demand anchoring, and technically inadequate dredging in a dynamic hydrological environment.

10.3 Political Economy Insights

The analysis reveals that political economy factors—corruption, policy discontinuity, elite capture—operate as binding constraints on infrastructure effectiveness. These dynamics cannot be treated as peripheral to technical and economic analysis but must be integrated into any realistic assessment of implementation feasibility.

The enhanced framework ($P = I \times D \times T \times G$) incorporating governance quality provides more accurate predictions of success probability and highlights the centrality of institutional reform as a prerequisite for infrastructure effectiveness.

10.4 Policy Implications for Nigeria

Immediate Actions:

- Establish Niger–Benue Corridor Authority with statutory autonomy and international oversight
- Secure binding cargo commitments from anchor industries before major capital deployment
- Implement pilot canalization and lock systems to demonstrate technical viability

Medium-term Strategy:

- Phase corridor development based on demand-led sequencing rather than geographic logic
- Structure PPP frameworks with performance incentives and risk-sharing mechanisms
- Integrate corridor development with broader industrial and regional trade policy

Long-term Vision:

- Position Nigeria as West Africa's multimodal logistics hub under AfCFTA framework
- Achieve transport cost competitiveness matching global corridor systems
- Generate sustained employment and industrial development along the corridor belt

10.5 Broader Implications for Infrastructure Policy

For developing economies pursuing infrastructure-led development, this study demonstrates that alignment precedes impact. Physical construction without corresponding institutional, market, and governance alignment produces "assets without utilization"—infrastructure that exists in form but not in function.

Strategic principles:

- System-first approach: Build coordination mechanisms before deploying capital
- Demand validation: Secure credible utilization commitments before construction
- Performance discipline: Link financing to verified functional outcomes rather than completion milestones
- Governance integration: Treat corruption control and accountability as infrastructure prerequisites

10.6 Future Research Directions

This framework opens several avenues for future investigation:

- **Quantitative testing:** Statistical validation across larger samples of infrastructure projects
- **Sectoral expansion:** Application to rail, energy, and urban transport systems
- **Governance modeling**: Deeper analysis of institutional design for complex infrastructure coordination
- **Dynamic analysis:** Longitudinal studies of how system alignment evolves over project lifecycles

10.7 Final Assessment

Nigeria's Niger–Benue corridor possesses the geographic, industrial, and market fundamentals for successful inland waterway development. What it lacks—and what the Warri–Baro project failed to provide—is the institutional architecture necessary to align these fundamentals into a functional system.

The path forward is not additional dredging or larger capital expenditure, but systematic institutional reform that creates the governance, market, and technical conditions under which infrastructure investments can generate sustained economic value. This requires recognizing that in developing contexts, building systems is more challenging—and more important—than building infrastructure.

The central lesson is that infrastructure becomes economically transformative only when governance, markets, and engineering are aligned within a coherent system. In their absence, investment produces assets without utilization—projects that exist in form but not in function.

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APPENDIX

A. Scoring Rubric

Appendix A: System Alignment Framework Scoring Rubric

Institutional Coordination (I) — Weighted composite (equal weights)

- Agency fragmentation: 1 - (n_agencies_with_overlap / 10) [max 10]
- Budget predictability: 1 - (std_dev_budget / mean_budget) over 5 years
- Policy continuity: % projects completed as originally designed
- Accountability: binary (1 if public audit + performance reporting exists)

Demand Anchoring (D)

- Cargo commitment ratio: binding throughput agreements / projected capacity
- Industrial utilization: average % capacity of corridor-adjacent industries
- Modal shift potential: current road/rail freight (Mt) amenable to water
- Value chain integration: scale 0-1 based on vertical linkage presence

Technical Sustainability (T)

- Navigation reliability: months/year with depth ≥ 2.5m
- Hydrological control: binary (1 if locks/canalization present)
- Maintenance efficiency: required dredging (m^3/year per km)
- Climate resilience: adaptive capacity score (0-1)

Governance Quality (G) — Moderator

- Corruption control: TI Corruption Perceptions Index (scaled 0-1)

- Policy continuity: government transitions without project abandonment (5-year)
- Accountability: EITI compliance + public procurement transparency

Appendix B: Data Sources and Demand Estimation Methodology

B1. Data Sources

Table B1 documents the primary datasets and reports used to derive baseline production, capacity, and freight potential across the Niger–Benue corridor.

Table B1: Core Data Sources

Variable	Description	Source	Year
Cement production & capacity	Plant-level capacity and national output (Obajana, Gboko)	Dangote Cement Plc, Annual Report	2023
Agricultural output	State-level crop production (Benue, Kogi, Nasarawa)	National Bureau of Statistics (NBS), *Crop Production Report*	2022
Trade flows (proxy)	National and regional trade volumes	NBS, *Foreign Trade in Goods Statistics*	2022
Iron ore production	Output estimates for Itakpe (NIOMCO)	Ministry of Mines & Steel Development	2022
Steel capacity	Installed capacity of Ajaokuta Steel Plant	Federal Government of Nigeria policy documents	Various
Inland water transport context	Inland waterway usage and constraints	National Inland Waterways Authority (NIWA) reports	Various

B2. Estimation Methodology

B2.1 Industrial Bulk Cargo (Cement, Steel, Iron Ore)

Freight potential is derived from installed production capacity, adjusted for realistic utilization and modal capture:

Freight Potential=Installed Capacity×Utilization Rate×Modal Capture Rate

Where:

- **Utilization Rate** = 60–80% (reflecting operational constraints in Nigeria's industrial sector)
- **Modal Capture Rate** = 50–75% (share of bulk cargo likely to shift from road to waterways)

Example (Obajana Cement):
16.25 Mt × 0.75 × 0.7 ≈ 8.5 Mt/year

B2.2 Agricultural Freight

Agricultural transport demand is estimated from **marketed surplus**, not total production:

Freight Volume=Total Output×Marketed Surplus Ratio

Where:

- Marketed Surplus Ratio = 60–70%
- Adjustments applied for:
  - post-harvest losses
  - local consumption

B2.3 Trade and Commercial Freight (Onitsha Axis)

Due to absence of direct freight datasets, trade flows are proxied using:

- NBS trade statistics
- Corridor-level logistics intensity assumptions
- Observed truck traffic patterns in the South-East

Freight Proxy=Trade Volume× Freight Intensity Coefficient

This produces a **range estimate (8–12 Mt/year)** rather than a point estimate.

B2.4 Aggregation Framework

Total corridor demand is computed as:

D=Dindustrial+Dtrade+Dagriculture

Yielding:

- **Baseline demand:** 36–55 Mt/year
- **Expanded demand (with induced effects):** 43–68 Mt/year

Induced demand reflects:

- modal shift acceleration
- cost-induced output expansion
- logistics clustering effects

B3. Key Assumptions and Limitations

1. **Ajaokuta Steel Plant**

   Treated as latent capacity, not current output, due to limited operational activity.

2. **Data Gaps**
   - Lack of corridor-specific freight surveys
   - Limited transparency in mining output data

3. **Estimation Approach**
   - Combines observed data + calibrated assumptions

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- Uses range estimates to reflect uncertainty

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