

RE-ARCHITECTING AFRICAN FREIGHT

How Movement Can Build Africa's
Productive Economy



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Publication note

This monograph presents an authored strategic and methodological framework. Established and source-reported evidence is distinguished from propositions, scenarios and research requirements. The framework does not substitute for project feasibility studies, statutory appraisal, operator quotations or route-specific due diligence; it provides the architecture within which those decisions can be tested consistently.

Professional disclosure. The author has undertaken professional strategic and advisory work related to selected geographies discussed in this monograph, including Mombasa, Durban and Cotonou. These cases are used analytically; propositions arising from that work are distinguished from independently sourced evidence through the evidence-status protocol.

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EXECUTIVE OVERVIEW

The problem. Africa is not simply facing a transport-decarbonisation problem. It is building a larger physical economy: more cities, more industrial production, more regional trade, more food movement, more energy demand and more complex value chains. Much of the inherited freight geography was designed to evacuate commodities toward ports. An industrialising Africa requires a different architecture: one capable of moving raw materials, intermediates, components, food, parcels and finished goods through productive territories, industrial nodes, cities and gateways without allowing movement itself to become the measure of success.

The central thesis. This monograph argues that Africa should not decarbonise an inefficient freight architecture. It should re-architect freight so that unnecessary movement declines, necessary movement becomes more productive, appropriate modes and energy systems are used, interfaces become more reliable, and the physical economy creates progressively greater productive value with lower resource and carbon intensity. The governing decision rule is: Right freight. Right mode. Right energy. Right infrastructure. Right geography. Greater Productive Yield.

What is new. The work brings freight economics, industrial geography, energy, urban systems, political economy and evidence discipline into one decision architecture. Productive Density moves analysis beyond tonnes toward mass, volume, value, transport work and transformation. Fossil-Smart eliminates avoidable fossil-energy consumption and makes remaining use measured, efficient and disciplined, while reducing lifecycle intensity and preserving the transition to cleaner energy.

Productive Yield asks what capability and retained value remain after movement: processing, supplier depth, skills, enterprise development, capital formation, resilience and reinvestment. Total Route Cost forces modal choices to be tested door to door rather than by line-haul price alone.

The Avoid, Optimise, Shift and Clean sequence establishes the order: first remove movement generated by inefficiency, then improve necessary movement, reassign suitable freight to the right mode, and clean the remaining energy and assets.

The metropolitan proposition. The city is treated as part of the freight system, not the place where corridor analysis ends. African metropolitan economies combine formal and informal enterprise, physical markets and social commerce, cash and electronic money, motorcycles and minibuses, rail and BRT, walking and cycling, conventional freight and CEP. The manuscript therefore treats urban logistics and passenger mobility as a shared circulation problem. Dense, predictable flows should use high-capacity trunks where they are viable; fragmented origins and destinations require flexible first- and last-mile systems. Digital visibility should aggregate demand before another vehicle trip is created. Technology should serve the economic and social identity of African cities rather than force those cities into an imported operating model.

What decisions this changes. For governments, the question becomes which modal, access, land use, border and investment rules produce the strongest whole-system outcome. For ports and infrastructure managers, it becomes how interfaces, staging, rail and water access, data and energy should work together. For operators, it is whether a service works commercially across the complete route under real utilisation, dwell, labour, energy and reliability conditions. For industrial and SEZ investors, it is where production can be located so that resources, utilities, skills, logistics and markets create defensible economics. For financiers, it is whether evidence, demand and risk allocation are strong enough to make the architecture bankable.

How the book should be used. This is a strategic monograph, not a claim that one mode, fuel, urban form or corridor model should be imposed across Africa. The architecture is continental; the answer is geographical. The nine laboratories are used as stress tests because they expose different combinations of cargo, density, regulation, energy and institutional capability. The evidence-status protocol distinguishes established evidence, source-reported evidence, propositions, scenarios and research requirements. The work is intended to generate better decisions and testable propositions, not to replace route-level feasibility, operator data or institutional validation.

Empirical programme. The architecture is complete as a decision framework; its applications are deliberately evidence-dependent. African freight decisions require stronger origin-destination data, current tariffs, utilisation, dwell distributions, energy use, emissions, access regimes, commercial structure and value-retention evidence. Where a proposed modal shift, technology or project does not work under real conditions, the framework must be capable of saying no. Where it works only under specific conditions, those conditions must be explicit. The ambition is not maximum movement. It is a physical economy in which movement becomes an input into productive transformation rather than an end in itself.

EXECUTIVE OVERVIEW • WATERBORNE FREIGHT INTEGRATION

The architecture also brings Africa's inland waterways, lakes and coastal waters into the freight decision system. Water is neither presumed superior nor treated as peripheral: river, lake and short-sea services are tested alongside road, rail, air and pipeline according to cargo suitability, complete-route economics, resilience, energy and Productive Yield.

HOW TO READ THE EVIDENCE

This edition distinguishes doctrine from observation through two related but different evidence systems. Claim markers describe what a statement is: [E] established evidence; [SR] source-reported evidence; [P] an analytical or design proposition; [S] a scenario assumption; and [R] a research requirement. Input-maturity states describe the quality of a variable used inside the decision model: Measured, Reconciled, Estimated, Scenario or Unknown. A marker or maturity state does not replace a source note: externally contestable quantitative claims remain tied to identified sources in the notes and evidence base.

Table 1. Claim markers and interpretation

Claim marker	Meaning
[E]	Established evidence from a traceable source.
[SR]	Source-reported; not independently validated here.
[P]	Authored analytical or design proposition.
[S]	Explicit scenario assumption.
[R]	Research evidence still required.

Table 2. Input maturity and interpretation

Input maturity	Permitted interpretation
Measured	Direct observation for the defined route, asset and period.
Reconciled	Traceable sources cross-checked with consistent boundaries.
Estimated	Stated calculation and evidence base; test a range.
Scenario	Future or illustrative assumption; never present as observed.
Unknown	No point conclusion if the missing input can reverse the decision.

The crosswalk is deliberate. An [E] claim may rely on a Measured or Reconciled input; an [SR] claim remains source-reported unless independently reconciled; an [S] claim maps to a Scenario input; and an [R] claim normally maps to an Unknown input until evidence is obtained. Estimated inputs must state the method and evidence base. The reader-facing test is simpler: every important factual statement should be traceable, every scenario should be labelled, and every proposition should remain distinguishable from an observed outcome.

The architecture at a glance

Table 3. Economic architecture at a glance

Layer	Role in the argument	Where to use it
Economic transformation	Defines the development objective before transport assets are selected.	Introduction; Chapters I, VI-VII
Intelligent Corridor operating system	Coordinates five flows, productive nodes, interfaces and market access.	Introduction; Chapters II-III, VIII
Resource-to-Market chain	Traces transformation, revenue, retention and reinvestment through to the end user.	Chapter I; Chapters VII-VIII
Productive Freight Decision Model	Tests cost, density, yield, energy, carbon and resilience under common boundaries.	Chapter IX; Annexes A-B
Evidence and implementation	Distinguishes propositions, published observations, scenarios and decision-grade inputs.	Chapter X; Annexes C-D

PROLOGUE • THE FREIGHT SYSTEM AFRICA IS ABOUT TO NEED

Africa is preparing to build an economy whose physical requirements will be very different from those of the economy it inherited. The continent must industrialise, feed and power a growing population, connect larger cities, deepen regional markets, expand productive territories and compete in a trading system increasingly shaped by carbon, technology, resilience and geopolitical fragmentation. Each of these transformations has a physical consequence. Something must be produced somewhere. Energy must reach it. Inputs must arrive. Goods must be stored, transformed and distributed. Markets must be served. Freight is therefore not a technical afterthought to African development. It is one of the physical expressions of development itself.

Yet much of Africa's transport geography still reflects an older economic logic. Railways, roads and ports were frequently organised around the evacuation of commodities from interior territories to coastal gateways. Modernisation has improved many assets, but the underlying measure of success often remains movement: tonnes handled, containers moved, trucks cleared, vessels called, kilometres built. Those measures matter. They do not tell us whether the movement is building a deeper economy.

An industrialising Africa changes the question. Cotton can become yarn, fabric and garments.

Cocoa can become butter, powder, ingredients and branded food. Minerals can be concentrated, refined and incorporated into manufactured products. Agricultural output can be graded, cooled, processed and packaged closer to production. Components can move between African industrial centres before becoming finished goods. The physical system is no longer merely evacuating weight. It is coordinating transformation.

What freight system does an industrialising Africa actually require?

That is the question of this monograph. It is deliberately larger than decarbonising trucks, replacing diesel equipment or installing solar panels at ports. Those interventions can matter greatly, but they come after a more fundamental design problem: what should move, why should it move, where should transformation occur, which mode should perform each part of the journey, what energy should power it, and how much productive value should remain in the territories through which the system passes?

The argument developed here is that Africa's first freight transition is architectural. It is a transition from moving weight to enabling productive value; from treating modes as separate sectors to allocating freight intelligently across them; from treating energy as a fuel question to treating it as a productive system; and from measuring corridor success primarily through throughput to asking what movement leaves behind.

Decarbonisation then becomes part of a larger transformation. The objective is not to impose scarcity on a continent that still needs substantially more energy, infrastructure and productive activity. It is to make expanding development progressively less wasteful: less unnecessary movement, less idle time, less empty running, less congestion, lower energy and carbon intensity per unit of productive value, and greater African capability and value retention.

The task is not to move the greatest possible quantity of goods. It is to create progressively greater productive value from necessary movement.

Introduction: the economic architecture behind freight

Why economic transformation comes first

The usual freight question is operational: how do we move cargo faster and more cheaply? The climate question adds another dimension: how do we move it with fewer emissions? Both are necessary, but neither is sufficient for an African development strategy. A freight system can be fast, digital and lower-carbon while still carrying an economy dominated by low-value extraction and imported finished goods. It can be efficient without being transformative. The African freight question must therefore begin one level higher: what economy is the freight system being asked to build? Once that question is asked, logistics, industrial policy, energy, land use, cities, ports, SEZs, enterprise development, finance and trade facilitation can no longer be designed in isolation. This is where the wider Africa Intelligent Corridors body of work matters.

Its contribution to this monograph is not a branded definition imposed on every chapter. It is an operating logic: movement should connect productive capability to markets and opportunities, and the physical system should progressively convert flows into value that can be created, transformed, retained, circulated, reinvested and compounded. The five flows , goods, people, capital, knowledge and data , move together even when freight is the visible surface.

Africa's transition cannot be designed as if the continent's principal problem were excessive energy abundance, excessive industrial capacity or excessive infrastructure. The continent still faces major electricity-access gaps and large infrastructure and industrial deficits. The correct objective is therefore productive abundance: more reliable energy, more capable enterprises, more industrial production, stronger food systems, deeper regional trade and better infrastructure, with progressively lower waste, friction and lifecycle carbon intensity per unit of value created. This distinction is decisive. A mature economy may focus heavily on replacing an existing vehicle stock. An African economy may simultaneously need to build the road, rehabilitate the railway, modernise the port, establish the industrial zone, finance the operator, connect the electricity system, create the data layer and grow the market. The transition is therefore a systems-design problem.

The physical economy and its five flows

The governing freight intervention sequence remains Avoid, Optimise, Shift and Clean. Avoid removes movement generated by inefficiency. Optimise consolidates and improves necessary movement. Shift allocates suitable freight to the mode that performs the complete journey best. Clean then reduces the resource and carbon intensity of the movement and assets that remain.

Trade and commerce. The exchange and organisation of economic value across producers, enterprises, territories and markets. In this monograph, trade is not reduced to border crossing; it depends on the productive, logistical, financial, informational and institutional systems that make exchange possible.

Movement. The physical or systemic transfer of people, goods, energy and other economically relevant flows between places, actors and productive functions. Movement connects production, transformation, exchange and consumption. It consumes time, infrastructure, capital, land and energy and therefore should not be maximised for its own sake.

Circulation. The wider system through which economic activity moves and coordinates. Physical movement of goods and people interacts with capital, knowledge and data; energy enables the physical layers; trust and institutions allow shared systems to function.

Density. The concentration of useful physical, economic and productive value within movement and geography. Density can appear as higher utilisation and consolidation, greater value per tonne or cubic metre, deeper processing, stronger transaction concentration, or productive clustering.

Productive Density. The economic and productive value embodied in what moves, read alongside mass, volume, transport work and processing stage. It asks not merely how much moves, but what the movement economically contains.

Productive Yield. The additional productive capability and retained value that exist because a freight, corridor, urban, energy or infrastructure system is built or improved. Its canonical dimensions are Transformation, Enterprise, Capability Development, Retention, Market Access, Spatial Diffusion, Resilience and Compounding.

Physical economy. The connected system of production, transformation, storage, energy, infrastructure, logistics, cities, gateways and physical movement through which economic value is created and exchanged.

The central thesis is that Africa should not decarbonise an inefficient freight architecture. It should re-architect movement so that unnecessary physical movement declines, necessary movement becomes denser and more productive, appropriate modes and energy systems are used, interfaces become more reliable, and the physical economy creates progressively greater productive value with lower resource and carbon intensity.

Reducing movement is therefore not an austerity objective. It is an architectural objective. Empty running, fragmented deliveries, repeated handling, avoidable repositioning, congestion-induced kilometres, weak demand aggregation and unnecessary supply-chain distance consume resources without proportionate productive return. The first task is to remove or redesign those movements.

The second task is to increase the density of what remains: consolidate demand, improve utilisation, increase load factors, locate transformation intelligently, increase value per tonne and per cubic metre, improve return flows, reduce waiting and make interfaces more reliable. As productive transformation deepens, the form, value, time-sensitivity and handling requirements of freight also change.

The objective is not less economic activity. It is more access, exchange and Productive Yield per unit of physical movement, energy, infrastructure and carbon.

The central question: what movement architecture does the next African economy require?

The governing principle of productive circulation

Do not maximise movement. Maximise productive circulation.

Less unnecessary movement + denser necessary movement + greater productive value per movement = a more productive physical economy.

Move less where movement adds no value. Move better where movement is necessary. Create more value from every movement that remains.

This does not mean reducing trade, commerce, access, mobility or economic activity. The objective is the opposite: more productive exchange, access and economic activity without requiring

proportionally more physical transport work. Movement is an input into economic transformation, not an end in itself.

The architecture coordinates five economic flows: goods, people, capital, data and knowledge. Energy enables physical production and movement. Services support transactions, transformation and exchange; they should not silently replace one of the five flows in the corridor taxonomy.

The integrated corridor and circulation architecture recognises five flows: Goods, People, Capital, Knowledge and Data. They do not all move in the same physical sense. Goods and people require physical movement; capital, knowledge and data circulate through financial, institutional, human and digital systems. Their interaction determines whether physical movement becomes productive transformation.

The AIC2030 trade doctrine defines trade more broadly than the exchange of goods and services: it treats trade as the organised circulation of goods, capital, energy, information and trust across space, through systems designed to transform geography into prosperity. This monograph keeps that doctrine intact and makes its physical implication explicit. Freight is the circulation of goods within a wider economic system in which people, money, information, knowledge, services and energy continuously interact. [P] At metropolitan scale, people and services must become explicit in the analysis because workers, consumers, entrepreneurs, couriers, service providers and institutions are themselves part of the circulation through which markets function. This is an analytical extension of the trade doctrine, not a replacement for it.

The question is therefore larger than how cargo moves: it is how an economy organises circulation so that more value can be created and accessed with less friction, unnecessary physical movement and energy waste. [P] The distinction matters. Digital money can move without a vehicle. Information can coordinate demand before a trip begins. A social-commerce order can create a data flow, a payment flow and then a parcel movement. A worker journey can connect labour to production. Energy powers the physical layers that cannot be dematerialised. Trust determines whether people, enterprises and institutions are willing to participate in shared systems. Freight remains the subject of this monograph, but it is analysed as one of the principal physical expressions of a larger architecture of circulation. [P]

Doctrine, architecture and operating system

Three levels must remain distinct. First, the architecture: Africa's physical economy must organise the movement and circulation required by an industrialising continent. Second, the operating geography: corridors, gateway cities and productive territories connect resources, production, people, energy, services and markets end-to-end. Third, the methodology: the Productive Freight Decision Model tests the specific choices made inside that architecture. The architecture is not a claim that one mode or technology will always win; the method exists precisely because those choices must remain empirical. [P] The corridor is therefore more than a line between infrastructure assets. It is the spatial system in which productive territories, transformation nodes, cities, gateways, modes, energy systems and markets are coordinated around actual economic flows.

Goods, people, capital, knowledge and data move through this geography, while energy enables its physical layers. Corridor performance must consequently be judged not only by throughput or travel time, but also by the productive capability the system creates, retains, circulates and compounds. [P]

The economic transformation hierarchy

Africa's Economic Transformation guides the Physical Economy and Circulation Architecture. Corridors, Gateway Cities and Productive Territories organise Freight, Modes, Energy, Infrastructure and Interfaces. Productive Yield tests the resulting outcomes. [P]

This hierarchy places the development objective above the physical economy, identifies its operating geography, locates freight and its enabling systems within that geography, and tests their contribution through Productive Yield. The following implementation map and Figure 2 explain how the doctrine is applied; they complement this economic hierarchy. [P]

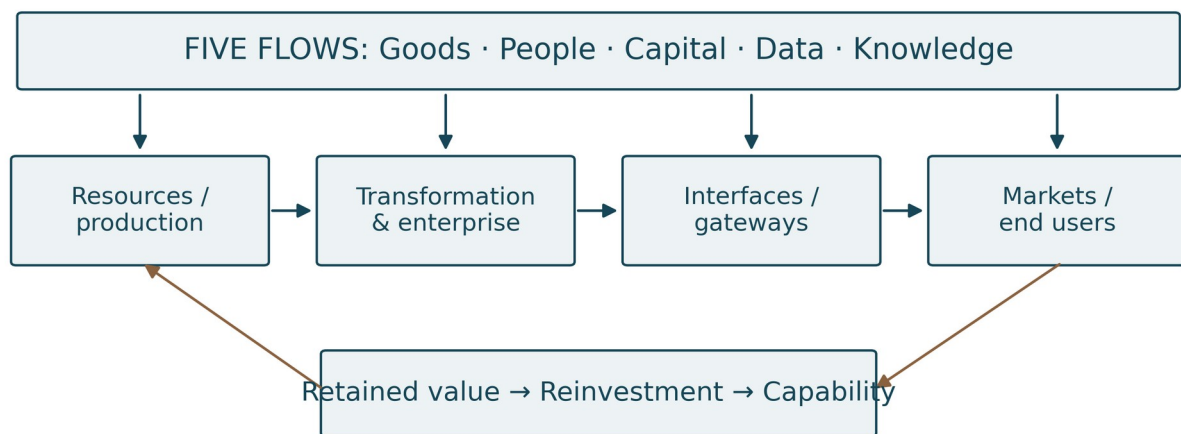
Within this hierarchy, economic transformation guides the physical economy and circulation architecture. Corridors, gateway cities and productive territories connect the five flows through modes, infrastructure, interfaces and energy systems. The objective is productive value that is created, retained, circulated, reinvested and compounded. Services and energy enable the five flows rather than replacing them. [P]

The supplementary implementation map begins with economic doctrine, which guides continental economic architecture. The Intelligent Corridor operating system connects resource-to-market and metropolitan systems, informing configuration choices. Evidence and measurement test those choices; implementation and feedback refine them. The corridor is an operating system within the wider economic architecture, not a synonym for a road or a digital platform.

The Intelligent Corridor: canonical definition

An Intelligent Corridor is an end-to-end economic system that connects infrastructure and economic flows to productive capabilities, markets and economic opportunities so that movement generates progressively greater productive value across the geographies it connects. It extends the corridor from movement to productive value, from gateway to end user and, where applicable, from land through the port into the ocean economy, while using data and digital intelligence to make the system more visible, connected, coordinated and adaptive, and progressively reducing its carbon and resource intensity. Its intelligence is ultimately demonstrated not by technology or movement alone, but by its capacity to convert economic flows into enduring and reproducible productive capability , creating, transforming, retaining, circulating, reinvesting and compounding value.

An Intelligent Corridor converts movement into productive value and connects that value end-to-end across the economic system.



Data, institutions and energy coordinate the complete system.

Figure 1. Intelligent Corridor Operating System

The resource-to-market productive chain

The productive chain runs from resource and first transformation through processing, industrial production, logistics, gateway and market to the end user. Supplier formation, skills, ownership and retained value must be traced across the chain. Retention and reinvestment feed back into new capabilities rather than ending at the gateway.

Governing proposition and design guardrails

Right freight. Right mode. Right energy. Right infrastructure. Right geography. Greater Productive Yield. The phrase is not a slogan for modal substitution. It is a decision rule. The right freight means understanding cargo characteristics and productive purpose. The right mode means assigning the trunk, feeder and first/last-mile movements according to cost, time, reliability, capacity, carbon and resilience. The right energy means matching technology to duty cycle and local energy reality. The right infrastructure means building interfaces that can evolve. The right geography means locating transformation where the combined economics of resources, energy, water, skills, land, logistics and markets are strongest. Productive Yield asks what economic capability and retained value result from the system. [P]

This monograph proposes a continent-wide decision architecture, not one uniform African freight model. The architecture is the proposition for how the physical economy should be connected; the methodology tests the choices made within it. The same questions must be asked across different geographies, but the answers will differ by cargo, density, market, energy availability, institutional capacity, urban form, infrastructure, regulation and commercial structure. A landlocked mineral system, a coastal megaregion, an island economy and a metropolitan food-distribution system should not be expected to produce the same modal or energy answer. The framework is intended to travel across the continent; the answer is not. [P]

The economic hierarchy does not replace the five-flow corridor doctrine. Goods, people, capital, knowledge and data remain the canonical corridor flows. Services and energy are made explicit here because the wider circulation architecture must also account for the services through which markets function and the energy that enables the physical economy. Freight remains the entry point of the book; the deeper subject is the architecture of movement required by the economy Africa is seeking to build. [P]

No mode is presumed superior. Road, rail, river, lake, short-sea, air and pipeline must earn their role through cargo, service, geography and complete-route economics.

No lower-carbon option is automatically called cheaper, more reliable or more productive.

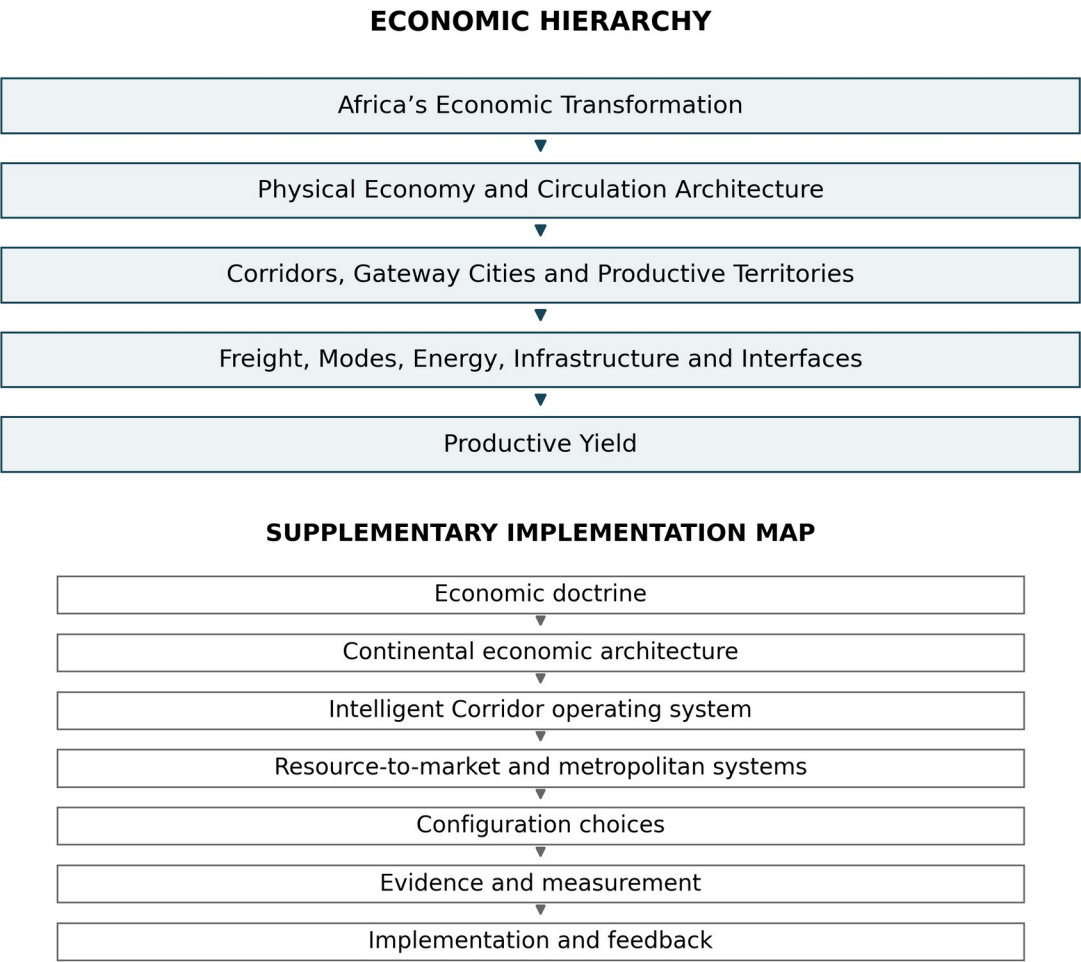
No double counting between conventional appraisal, wider benefits and Productive Yield.

No point conclusion where an Unknown decision-critical variable can reverse the decision.

No technology layer is allowed to digitise dysfunction; system architecture precedes digitalisation.

No infrastructure proposition is treated as productive transformation unless the capability, retention and compounding mechanisms are explicit.

Avoid unnecessary or unproductive movement; optimise necessary movement; shift suitable trunk freight; clean the remaining assets and energy. Modal choice follows complete-route performance, cargo and service requirements, energy, resilience and Productive Yield. No mode is presumed superior.



The economic hierarchy sets purpose; the implementation map organises application.

Figure 2. Economic hierarchy and supplementary implementation map

THE PRODUCTIVE FREIGHT ECONOMY

Productive Freight Economy: Core Formulations

The productive freight economy begins with a distinction that governs the rest of the book: movement is an input; productive transformation is the objective. The system should therefore seek to reduce avoidable transport work while increasing the density and productive value of the movement that remains. Productive Density provides the lens for understanding what is embodied in freight; Productive Yield later tests what additional capability and retained value the system leaves behind. [P]

The complete economic chain connects resources with transformation, production, distribution and markets. Market activity generates revenue, which can be retained and reinvested. Freight is the physical connector across this chain. The sequence prevents the analysis from ending at delivery: revenue, retention and reinvestment determine whether movement contributes to compounding productive capability. [P]

Avoid-Shift-Improve is an established mitigation hierarchy. Its freight adaptation here is Avoid unproductive movement; Optimise necessary movement; Shift suitable trunk freight; Clean remaining assets and energy. [E; N1; N2]

The objective is not less economic activity. It is more productive exchange from less unnecessary physical movement. Avoidable kilometres, empty running, fragmented deliveries, repeated handling, poorly located transformation, weak demand aggregation, congestion-induced detours and unnecessary repositioning consume time, infrastructure, energy and capital without a proportionate productive return. [P]

Reducing such movement creates the conditions for density. Demand can be aggregated before vehicles move; loads can be consolidated; utilisation can rise; return flows can be developed; processing can occur where the combined economics of resources, energy, skills, logistics and markets justify it; and each necessary movement can carry greater physical, economic or productive value. [P]

Density in this monograph is therefore not a single measure. It includes physical density through utilisation and consolidation; economic density through value per tonne or cubic metre; Productive Density through the transformation embodied in what moves; transaction density through the aggregation of demand and supply; and productive-geography density where complementary production, services, skills, logistics, markets and infrastructure reinforce one another. [P]

This is why Avoid precedes Optimise, Shift and Clean. The first task is not to make every existing movement cleaner. It is to determine which movement should exist, which can be removed or shortened, which should be consolidated, and which must then be performed better. The ambition is not maximum movement. It is maximum productive circulation.

STATE OF AFRICAN FREIGHT • A CONTINENTAL BASELINE

The continent does not yet have one harmonised dataset that allows every corridor, port, mode and border to be compared on identical definitions. A useful baseline must therefore distinguish continent-wide indicators from corridor- and gateway-specific observations. The purpose of this

section is not to manufacture false comparability, but to establish the scale of the physical system this monograph seeks to re-architect.

Road remains the dominant surface mode. The African Development Bank reports that roads carry about 80% of goods and 90% of passenger traffic on the continent. This dominance explains why road flexibility remains indispensable, but it also shows why modal allocation matters: where dense, regular flows can shift to rail, water or coastal services, road capacity can be reserved for the movements for which flexibility creates the greatest value. [E]

Intra-African trade remains a minority share of Africa's total goods trade. The African Development Bank's 2023 cross-border corridor review reported it at about 18%. The implication is not simply that Africa should trade more with itself, but that a larger regional market will require physical distribution systems able to serve production networks, cities and enterprises across borders. [E]

Corridor friction can still impose very high costs. The World Bank's June 2026 Douala-Bangui programme reported transport costs as high as US\$270 per tonne, normal journey times of 9-12 days and 38 checkpoints in Cameroon alone, including 17 involving informal payments. The same programme frames the corridor as the route for more than 80% of the Central African Republic's external trade. [E] [N10]

Historic World Bank corridor work provides a useful warning about transport-price intensity even though its values should not be read as a current continental average: freight tariffs on selected African road corridors were reported at roughly US\$0.05-0.13 per tonne-kilometre versus US\$0.01-0.04 in other developing regions. The comparison is retained only as historical context; current route decisions require current quotations and operator economics. [E] [N19]

Gateway scale is also rising. Kenya Ports Authority reports that Mombasa handled 45.45 million tonnes and 2.11 million TEUs in 2025, including 15.88 million tonnes of transit cargo. Import cargo reached 36.0 million tonnes against 5.03 million tonnes of exports, an approximate 7:1 imbalance that makes backhaul, empty running and the productive composition of trade especially relevant. [N20]

Port Autonome d'Abidjan reports 46.9 million tonnes of net traffic in 2025. Nigerian Ports Authority reports 129.3 million tonnes of cargo throughput across Nigerian ports in 2025. These are not directly comparable measures of corridor performance, but they show the scale of freight that increasingly interacts with metropolitan distribution, industrial systems and regional markets. [SR] [N21] [N22]

South Africa illustrates the parallel challenge of rebuilding rail capacity. Transnet Rail Infrastructure Manager announced 11 private Train Operating Companies allocated slots across five strategic corridors in May 2026, with the allocations expected to add about 24 million tonnes of freight capacity. The point is not that private access is itself the solution; it is that freight architecture increasingly depends on the institutional rules governing access to existing infrastructure. [SR]

This baseline produces a simple diagnosis. Africa's freight system is simultaneously road-dominant, gateway-intensive, institutionally fragmented and increasingly shaped by regional integration, urbanisation and new access regimes. The monograph's frameworks should therefore be judged against whether they reduce total route friction, allocate modes more intelligently, improve urban circulation, deepen productive capability and make evidence good enough for investment decisions.

1. Industrialisation changes freight

Industrialisation does not simply mean more freight. It changes the composition, geography, frequency, handling requirements and economic density of freight. A raw-material economy may move enormous mass over long distances while retaining little value. A transforming economy can create more domestic and regional movements, inputs, intermediates, packaging, machinery, components and finished goods, while increasing the value embodied in each tonne ultimately traded. [P]

This is why the relationship between economic growth and freight weight deserves greater precision. Total freight may still rise substantially as Africa urbanises and industrialises.

Construction alone can move huge volumes of cement, steel and aggregates. Food systems, machinery, chemicals and consumer goods will also expand. But the strategic objective should be for productive value to grow faster than the physical weight, energy and carbon required to generate it.

More tonnes are not the same thing as more prosperity.

2. From tonnage to Productive Density

Tonnes remain indispensable, but they are only one physical dimension. Transport assets can weigh out or cube out. Bulk minerals, cement and petroleum are often constrained by mass.

Furniture, packaged consumer goods, appliances and many manufactured products can be constrained by volume. Container systems add load units; distribution systems add pallets, cases and individual units; time-sensitive supply chains add frequency and inventory requirements.

A freight architecture for industrialisation therefore needs a richer measurement language: tonnes and cubic metres; tonne-kilometres and cubic-metre-kilometres; TEUs, pallets and units; cargo value; value per tonne and value per cubic metre; energy consumed; lifecycle carbon; and, above all, productive value created and retained.

Cargo value is not the same as Productive Yield. A container of imported finished goods can have high commercial value density while contributing little domestic productive depth. Productive Yield asks whether the system develops processing, supplier networks, skills, enterprise capability, technology, tax base, export capacity and domestic capital formation.

What Productive Yield adds Productive Yield is not intended to rename conventional cost-benefit analysis, wider-economic-impact appraisal or a local-content scorecard. CBA asks whether monetisable social benefits and costs justify an intervention. Wider-economic-impact analysis examines effects such as productivity, agglomeration, labour-market change and induced investment beyond direct transport-user benefits. Local-content analysis asks how much procurement, employment or ownership is domestic. Productive Yield asks a different system question: what additional productive capability and retained value exist because the movement system is configured as it is, and do those gains circulate and compound across the productive geography? [P]

Its canonical dimensions are eight and remain unchanged throughout this monograph: Transformation; Enterprise; Capability Development; Retention; Market Access; Spatial Diffusion; Resilience; and Compounding. The six-part zone test - creation, depth, retention, diffusion, resilience and compounding - is a place-based diagnostic mapped onto these eight dimensions, not a second definition of Productive Yield. [P]

The distinction is consequential. A project may produce a positive conventional transport benefit while leaving productive structure largely unchanged. It may satisfy a local-content threshold without creating competitive supplier capability. It may generate agglomeration benefits while allowing much of the resulting value to exit the territory. Productive Yield therefore complements rather than replaces established appraisal: it forces the analyst to trace transformation, ownership and retention, capability, spatial diffusion, resilience and reinvestment through one auditable additionality framework. [P]

3. Productive freight demand

Not every tonne-kilometre is evidence of economic progress. Some movement exists because production and markets are genuinely separated. Some exists because infrastructure, warehousing, inventory information, border systems or industrial location are poorly designed. Empty truck returns, repeated urban crossings, unnecessary handling, poorly sequenced port releases and long-distance movement of material that could economically be processed closer to source are different forms of freight demand.

The distinction between freight demand and productive freight demand is therefore fundamental.

The objective is to enable all movement necessary for productive transformation while progressively eliminating movement generated by avoidable inefficiency. [P]

4. The productive geography of freight

Freight is created by geography. Rural productive territories generate agriculture, fisheries, minerals, energy and enterprise. Aggregation nodes consolidate flows. Secondary cities and industrial nodes provide labour, services and first-stage transformation. SEZs and industrial clusters can convert flows into higher-value products. Metropolitan economies concentrate demand, finance, knowledge and services. Gateways connect these systems to regional and global markets.

The planning question is not simply where to build a road. It is: what should be produced where, transformed where, stored where, consumed where and moved between which places, and by what mode and energy system?

This leads toward a distributed productive geography rather than automatic concentration at the port or capital city. In some chains, first transformation near source can reduce waste, preserve quality, create rural employment and raise value density before long-haul movement. In others, scale economies, energy, water, skills or market access may justify concentration at a major industrial node. The answer must be discovered through economics, not ideology.

5. SEZs as conversion nodes

An SEZ should be judged by what it converts. Raw material into processed material. Agricultural output into food product. Imported component into manufactured output. Knowledge into industrial capability. Capital into productive assets. Energy into competitive production. If the zone simply imports inputs, performs shallow operations and exports with weak domestic supplier linkages, it can generate throughput without generating transformation. [P]

The additionality test is therefore broader than occupancy or export value. Creation, depth, retention, diffusion, resilience and compounding should all be examined. What productive capabilities were created? How deep are supplier linkages? What value remains? Does capability diffuse beyond the

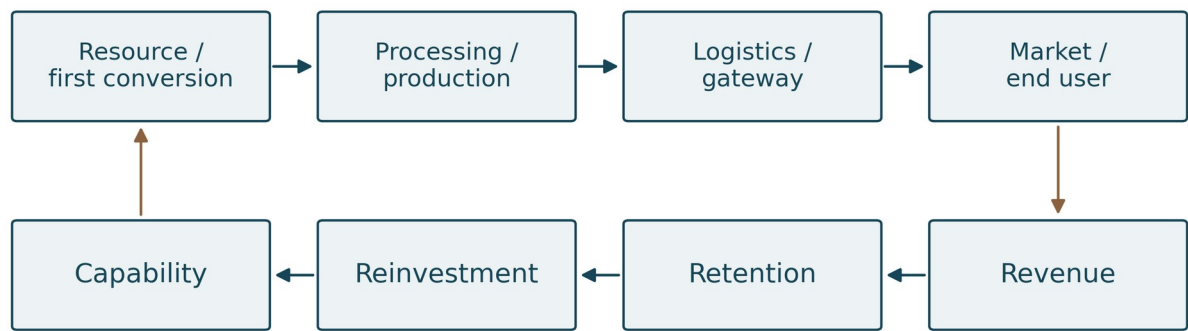
fence? Can the system withstand disruption? Does the resulting income and knowledge compound into new activity?

6. Commercial value and productive value

Commercial value asks what the cargo is worth in exchange. Productive value asks what capability the system creates and retains: processing, supplier depth, enterprise participation, skills, technology, ownership, tax base, domestic capital formation and reinvestment. A high-value imported finished product can have substantial commercial value while contributing little productive depth. A lower-value intermediate input can be strategically more important if it anchors local production, supplier capability and future exports.

Commercial value asks: what is the cargo worth? Productive value asks: what capability does the system create and retain?

7. The Resource-to-Market chain



Trace ownership, suppliers and skills; reinvestment feeds productive capability.

Figure 3. Resource-to-Market Productive Value Chain

The complete economic chain runs from resources through transformation, production and distribution to markets, revenue, retention and reinvestment. Freight physically connects its stages. Analysis must extend beyond delivery: revenue, retention and reinvestment determine whether movement contributes to compounding productive capability. [P]

8. Industrial Gravity and Capture by Measurement

Industrial Gravity describes the tendency of productive capability to attract and reinforce further capability. A processing plant can create demand for packaging, engineering, logistics, laboratories, energy services and finance; those capabilities can then serve other producers. As supplier density, specialised labour, market visibility and infrastructure deepen, the productive geography can become self-reinforcing.

Capture by Measurement is the counter-warning. Throughput, GDP, customs revenue or investment announcements can rise while productive depth, domestic ownership or supplier participation deteriorate. The answer is not to abandon conventional indicators but to place them inside a wider performance architecture that measures retained value, capability, enterprise depth, resilience and reinvestment.

Industrial Gravity is used here as a freight-and-production application of established agglomeration and clustering effects rather than as a claim to have discovered agglomeration economics. Capture by Measurement similarly applies Goodhart-type measurement risk to corridor performance: a metric can become a target and obscure the productive outcome it was meant to represent. [P]

9. Intellectual positioning: what this monograph builds on and what it adds

This monograph deliberately builds on established transport, logistics, economic-geography and carbon-accounting frameworks. Its contribution is the way those bodies of work are assembled around the future architecture of African freight and judged by productive capability and value retention. [E; N1; N2]

Table 4. Established frameworks and this monograph's contribution

Established framework	Use here	Distinctive extension
Avoid-Shift-Improve	Recognises the established mitigation hierarchy for transport.	Freight-specific adaptation: Avoid unproductive movement; Optimise necessary movement; Shift suitable trunk freight; Clean the remaining assets and energy.
Total logistics / landed cost	Door-to-door cost, inventory and handling are established logistics principles.	Total Route Cost is used as the common comparator for modal and decarbonisation choices.
Agglomeration / clustering	Explains concentration of firms, suppliers, skills and services.	Industrial Gravity focuses on how freight and productive capability reinforce one another spatially.
Goodhart-type measurement effects	Warns that targeted metrics can distort behaviour.	Capture by Measurement applies the warning to throughput, GDP, customs and corridor KPIs.
ISO 14083 / GLEC	Provides harmonised transport-chain GHG quantification and reporting.	Productive Carbon Yield is an additional developmental lens, not a substitute for physical emissions accounting.
Cost-benefit analysis and wider economic impact appraisal	Provides established methods for comparing monetised social costs and benefits, direct user impacts and, where justified, wider economic effects.	The Productive Freight Decision Model keeps CBA visible while adding freight-system, productive-depth, energy, carbon and resilience tests and explicit safeguards against double counting.
Multi-criteria / multi-objective decision analysis	Provides methods for comparing alternatives across multiple objectives when impacts cannot all be reduced credibly to one monetary metric.	The model uses feasibility gates, Pareto-style dominance, trade-off frontiers and explicit thresholds before any optional weighted presentation; it does not prescribe universal weights.

9A. Comparative lessons: evidence, not templates

The architecture is African, but it should not be intellectually isolated. International experience is useful when it tests a proposition rather than supplies a template. India's Eastern Dedicated Freight

Corridor demonstrates the interaction between dedicated freight capacity, reliability, modal shift and industrial geography. World Bank reporting describes freight-only electrified lines designed to reduce logistics costs, support industrial zones and release passenger capacity on existing railways.

The lesson is not that Africa should copy a dedicated-corridor model; it is that mode, capacity allocation, industrial location and passenger-freight interaction can be designed as one system. [E]

China's logistics experience provides a second test. ADB-supported work in Chongqing integrates road, rail, inland-waterway Ro-Ro, logistics parks, information systems and institutional capacity, while wider policy work emphasises interconnected inland waterways, rail container systems, multimodal hubs and logistics centres. It also supplies a warning: logistics clusters and corridors require flow evidence, economic justification and institutional integration; infrastructure concentration is not productive transformation by itself. [E]

African comparators outside the nine laboratories reinforce the same point. Tanger Med combines port, logistics and industrial platforms rather than treating the port as an isolated throughput asset.

The Addis-Djibouti system shows the opposite analytical necessity: dry port, corridor roads, rail, border processes and port performance must work together because failure at one interface can constrain the complete logistics system. These cases are not presented as models to imitate. They are comparative tests of the monograph's central proposition that productive freight performance emerges from integrated systems rather than isolated assets. [E]

A wider transformation architecture sits above that operational hierarchy. It progresses through Reduce, Densify, Optimise, Allocate, Power, Connect, Produce, Retain and Compound. The first is a freight intervention doctrine. The second describes how better movement becomes productive transformation. They are complementary and should not be collapsed into a single ladder.

The freight intervention hierarchy remains canonical: Avoid, Optimise, Shift and Clean. It governs the treatment of movement itself: remove movement that adds no value; increase density, utilisation and coordination of necessary movement; shift suitable flows to the appropriate mode; and then clean the remaining movement with the appropriate energy system.

No technically possible modal shift is called commercially viable without current operator economics. No technology layer is allowed to digitise dysfunction: system architecture precedes digitalisation. No infrastructure proposition is treated as productive transformation unless capability, retention and compounding mechanisms are explicit. No continental prescription overrides geography: the architecture is continental; the answer remains geographical.

No mode is presumed superior. Water is neither presumed superior nor treated as peripheral. River, lake and short-sea services must be tested alongside road, rail, air and pipeline against cargo suitability, complete-route economics, resilience, energy performance and Productive Yield.

RE-ARCHITECTING MOVEMENT

Water-Corridor and Modal Allocation Logic

Waterborne freight remains subject to the same modal-neutral, complete-route and Productive Yield tests as every other mode.

Inland-to-coast movement links production and aggregation via an inland waterway, inland port and multimodal interface to a maritime gateway. Gateway-to-gateway movement uses coastal services to connect that gateway to another African gateway, inland corridor and productive territory or market.

Cargo - What moves, in what volume, form, direction and season? Service - What frequency and reliability does the market require? Fleet - What vessel type, capacity, utilisation and operating economics are required? Interface - What does loading, unloading, storage and modal transfer add to cost and time? Access - How does cargo reach and leave the water system? Backhaul - What productive return flow exists? Productive Yield - What additional productive capability and retained value become possible because the water service exists?

A 2015 World Bank/EAC corridor study used an inland-water freight charge of US\$0.0808 per tonne-km for Mwanza-Port Bell and a lake-port nodal cost of US\$11.58 per tonne. These are historical modelling benchmarks, not current M.V. Mpungu tariffs. [SR/R] [N6]

Decision output. The multimodal option should not be described as preferable merely because the sailing leg is faster or potentially lower-carbon. It becomes a candidate for investment when it passes the commercial and service gates and its combined productive, energy, carbon and resilience performance is superior or represents an explicit, acceptable trade-off against the baseline. Until the [R] inputs are filled, the model should report thresholds and break-even conditions rather than a recommendation. [P]

Water Systems - commercially relevant rivers, lakes, lagoons, reservoirs and navigable sections. Water Gateways - inland ports, river ports, lake ports, metropolitan water terminals and multimodal transfer nodes. Productive Geography - agricultural systems, minerals, manufacturing, fisheries, energy, industrial zones, enterprise clusters, cities and markets connected to those nodes. Short-Sea Networks - coastal gateways, existing and proposed services, cabotage regimes, fleet requirements and potential gateway-to-gateway connections.

Waterborne integration. The architecture also brings Africa's inland waterways, lakes and coastal waters into the freight decision system. Water is neither presumed superior nor treated as peripheral: river, lake and short-sea services are tested alongside road, rail, air and pipeline according to cargo suitability, complete-route economics, resilience, energy and Productive Yield. This extends the monograph's existing multimodal logic without changing its governing principle: Right freight. Right mode. Right energy. Right infrastructure. Right geography. Greater Productive Yield.

10. Before changing the vehicle, question the movement

A great deal of transport decarbonisation begins with the propulsion system. The freight architecture proposed here begins one step earlier. Why is the movement occurring? Is the route necessary? Is the asset full? Is the cargo waiting? Is the return empty? Is the port release synchronised with the receiving warehouse? Is a long road haul being used because another mode is absent, unreliable or institutionally disconnected?

Before changing the energy source, eliminate the energy that should never have been consumed in the first place.

11. Avoid, Optimise, Shift and Clean

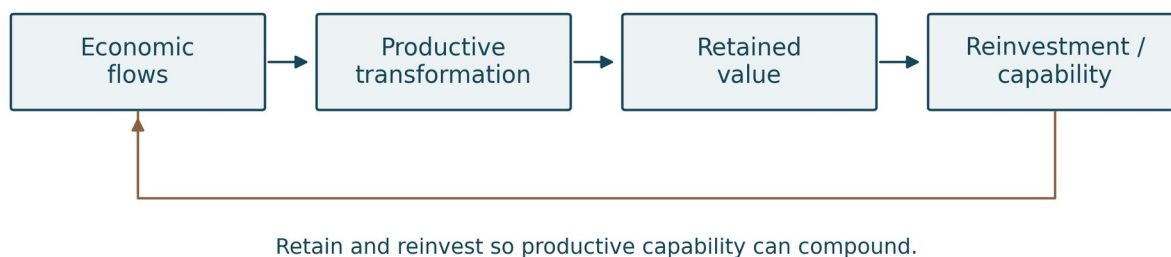


Figure 4. From Movement to Productive Circulation

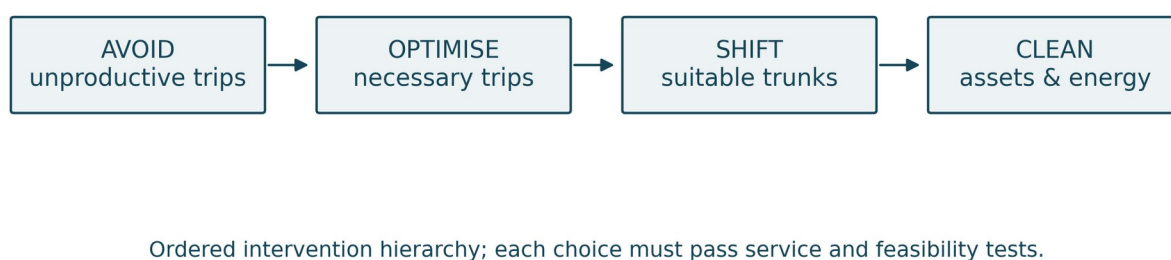


Figure 5. Avoid, Optimise, Shift, Clean

The sequence is intentionally ordered. Avoid means remove unproductive movement rather than suppress trade. Optimise means improve utilisation, scheduling, consolidation, visibility and interfaces. Shift means reassign suitable trunk freight to rail, inland waterways, lakes or coastal shipping where total-route economics justify it. Clean means progressively improve the energy and propulsion of the movement that remains. [P]

The sequence is not rigid. Electrification may proceed while operational reforms are under way; rail investment may be essential before optimisation is complete. Its value is analytical: it prevents the transition from becoming a technology-purchasing programme layered onto structural inefficiency.

12. Intelligent Modal Allocation

Road is indispensable to African freight. Its flexibility makes it exceptionally powerful for first and last mile, irregular flows, shorter distances, urgent cargo and locations without fixed infrastructure.

The problem is not the truck. The problem is using the truck for every task simply because the rest of the system is weak.

Modal intelligence asks which combination of road, rail, river, lake and sea provides the strongest balance of total cost, time, reliability, resilience, infrastructure requirement, energy and carbon for a specific cargo and route. Cargo density, perishability, value, shipment size, regularity, handling sensitivity and two-way flow potential matter. So do service frequency and utilisation. [P]

Move the right freight, by the right mode, at the right scale, through the right nodes.

Mode neutrality is a governing discipline: road, rail, inland waterway, coastal shipping, air and pipeline should be tested by cargo suitability and total system economics rather than treated as ideological winners or losers. [P]

13. The middle-mile reassignment

The most useful modal shift may be the one that does not attempt to eliminate trucking. A truck can collect cargo from the origin, board a RoRo vessel or deliver to rail, and resume the journey at the destination interface. The long middle section is reassigned while the flexibility of road is preserved at both ends. This is particularly relevant to lake and coastal systems.

14. The interface economy

Freight costs are not created only while a vehicle is moving. They accumulate at interfaces: ship to port, port to truck, truck to rail, rail to inland terminal, terminal to warehouse, border to border, lake to road, SEZ to corridor. Each transfer can add handling, dwell, inventory cost, information loss, customs friction and carbon. [P]

This is why a theoretically efficient mode can lose in practice. A cheap water leg surrounded by expensive, slow transfers may be inferior to a direct truck. A rail service with unreliable terminal release may impose working-capital costs that erase its line-haul advantage. The unit of analysis must therefore be the door-to-door system.

15. Time is capital

Transit time is not merely an operational KPI. It affects inventory, working capital, spoilage, production scheduling, customer service and investment attractiveness. Reliability can matter even more than average speed: firms can plan around a predictable two-day service more easily than a service that takes one day sometimes and five days at others.

Total Route Cost should therefore include line-haul, first and last mile, handling, dwell, inventory, border and compliance cost, reliability risk, energy and external infrastructure cost. The result is not a universal formula for selecting a mode; it is a discipline for preventing partial comparisons.

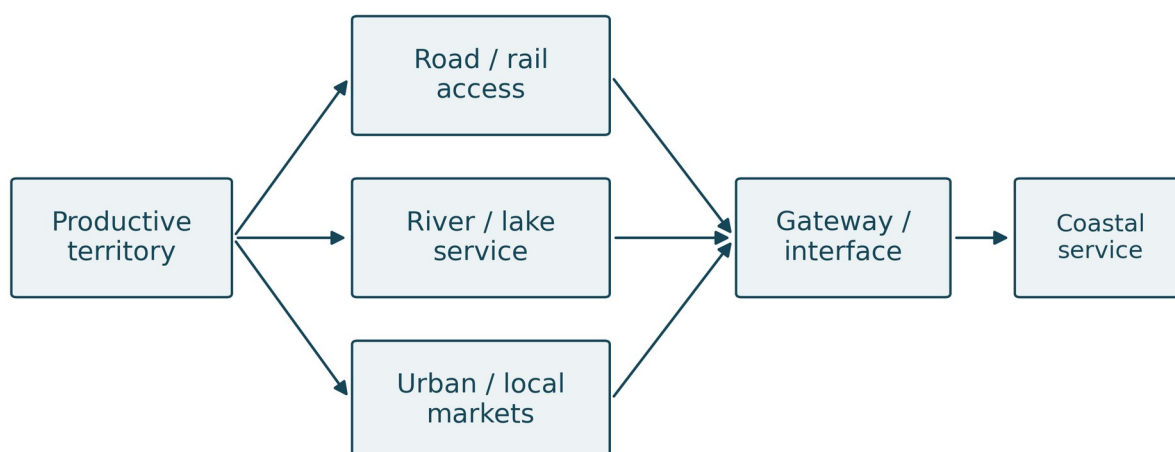
16. The Blue Freight Shift

Africa's lakes, rivers and coastlines create an obvious but frequently oversimplified opportunity.

Water can carry large loads with attractive energy characteristics, but geography alone does not create a freight system. Navigability, terminals, cargo density, service frequency, fleet quality, safety, first/last-mile connections, customs, regulation, insurance and operator economics determine whether water becomes commercially meaningful.

The Blue Freight Shift is therefore not advocacy for water. It is a systematic test of whether suitable freight can be reassigned to inland waterways, lakes, short-sea shipping and coastal feeder services when the total cost-carbon-time-reliability-resilience equation is superior.

16A. From Blue Freight Shift to African Water Corridors



Illustrative connected routes, not a mandatory sequence or proof of navigability.

Figure 6. African Water Corridor Architecture

The Blue Freight Shift becomes economically significant when water is treated not as an isolated mode, but as part of an end-to-end productive system. Africa's rivers, lakes, lagoons and coastal waters do not become corridors merely because vessels can move across them. Navigability is a physical condition. A corridor is an economic architecture. [P]

An African Water Corridor is an integrated economic system in which rivers, lakes, inland ports and coastal shipping connect with gateway cities, terrestrial infrastructure, productive capabilities and markets so that waterborne movement generates progressively greater productive value across the geographies it connects. [P]

The distinction is important. A navigable river without sufficient cargo density, terminals, fleet, first- and last-mile connectivity, predictable service, institutional coordination or productive catchment may remain economically marginal. Conversely, a waterway connected to agricultural production, industrial clusters, secondary cities, railways, roads, border systems and maritime gateways can become one component of a much larger productive corridor.

The architecture connects a productive territory and gateway city through a river or lake, an inland port and a multimodal interface to a maritime gateway. Short-sea shipping then connects that gateway to a second African gateway and a second productive territory.

Road and rail remain integral to this architecture. Water rarely eliminates terrestrial transport. It changes where different modes should perform the work. Road can aggregate dispersed production into an inland terminal; water can carry suitable dense middle-mile freight; rail can connect an inland port to an industrial cluster; coastal shipping can connect one gateway economy to another; road can again perform final distribution.

The strategic question is therefore not whether Africa should move more freight by water. It is: Where can Africa use water to move differently, and what productive value can that movement leave behind?

This is the waterborne application of Intelligent Modal Allocation.

17. Source to sea

The corridor does not stop at the shoreline. A productive freight system can connect production territory to river or lake, inland port, logistics platform, gateway port, coastal service, regional port and final

market. The useful question is not whether Africa should choose road or water. It is what modal architecture from source to market best serves the productive economy.

17A. Source to sea and gateway to gateway

Source-to-sea architecture should not be interpreted as another extraction route from an African interior to an export port. The productive objective is different. Movement should connect production territories to transformation nodes, African markets and regional production systems before, where commercially appropriate, connecting them to global markets. [P]

This creates two complementary directions of circulation.

Inland-to-coast movement links production and aggregation via an inland waterway, inland port and multimodal interface to a maritime gateway. Gateway-to-gateway movement links it by coastal service to another African gateway, inland corridor and productive territory or market. Together, these links can form an African waterborne circulation system, connecting waterways and ports.

This matters especially for landlocked and interior economies. Their effective maritime geography need not begin only at the coastal port. An inland lake or river port can become an economic gateway when it reliably connects productive territory to terrestrial corridors, regional markets and ultimately maritime networks.

The corridor is therefore continuous even when the mode changes. Corridor continuity is economic, not modal. Goods may move by road, rail, river, lake and sea during the same productive journey. Capital finances the movement and transformation; data coordinates it; knowledge develops the capabilities around it; people operate and participate in the economy it creates. [P]

18. Road as the flexibility layer

Road freight should not be treated either as the default trunk mode or as a mode to be displaced indiscriminately. Its distinctive strength is flexibility. Roads connect dispersed origins and destinations, respond quickly to changing demand, serve irregular consignments and perform first and last-mile functions that fixed modes often cannot.

In a more intelligently multimodal system, road can increasingly become the timing, flexibility and correction layer around rail, waterway and coastal trunk services. This reframes modal shift: the objective is not to remove trucks from the economy, but to reserve long-haul road capacity for freight and journeys where road's flexibility genuinely creates the greatest system value.

19. Cargo suitability, frequency, utilisation and backhaul

A mode cannot be judged by infrastructure alone. Cargo suitability includes density, perishability, value, time sensitivity, shipment size, regularity, hazard and handling requirements. Service frequency determines whether a theoretically efficient mode is usable. Utilisation determines whether high fixed-cost assets can reach competitive unit economics. Backhaul determines whether equipment returns productively or carries the cost and carbon of emptiness.

These variables are decisive for rail, inland waterways and short-sea shipping. A vessel may be energy-efficient per tonne-kilometre and still fail commercially if cargo is too irregular, port time is excessive or the return leg is empty. The freight architecture must therefore model the service, not merely the mode.

17B. Inland waterways as economic geography

The economic potential of a waterway cannot be assessed from the water alone. The relevant unit of analysis is the productive geography surrounding and connecting to it.

Table 5. Water-system assessment layers

Water-system layer	Required assessment
Water and hydrography	Navigable depth, width, seasonality, hydrological variability, sedimentation, dredging, locks, navigation aids, climate exposure and environmental constraints.
Movement	Existing and potential cargo, passengers, fleet, service frequency, ports, landing sites, handling systems and safety.
Interfaces	Connections with roads, railways, border posts, logistics platforms, ports, energy systems and digital infrastructure.
Productive geography	Agriculture, fisheries, minerals, manufacturing, energy, industrial zones, cities, population centres, enterprise clusters and markets within the economic catchment.
System architecture	Institutions, cross-border agreements, customs, regulation, safety, navigation management, data systems, finance and commercial operating structures.
Productive Yield	Whether the resulting architecture increases all eight canonical dimensions: Transformation, Enterprise, Capability Development, Retention, Market Access, Spatial Diffusion, Resilience and Compounding across the connected geography. [P]

A blue line on a map is not a corridor. The system becomes economically meaningful only when water, cargo, infrastructure, institutions and productive geography work together.

17C. Short-sea shipping: connecting African gateways

The second component of the Blue Freight Shift lies beyond inland waterways. Africa possesses a long coastline and a system of major and secondary ports, yet coastal proximity does not automatically create an integrated coastal freight market.

Short-sea shipping should therefore be examined as part of the continental freight architecture: scheduled coastal services capable of moving suitable freight between African gateways while connecting those gateways to their respective inland productive systems. [P]

The economic proposition is not simply to replace long-distance trucks with ships. A coastal service must compete on Total Route Cost after port charges, terminal handling, dwell, documentation, first and last mile, service frequency, inventory implications, reliability and backhaul are included.

Where those conditions work, short-sea shipping can perform another function: connecting Intelligent Corridors to one another.

An inland corridor connects to a maritime gateway, a short-sea service, a second maritime gateway and a second inland corridor. This changes the conceptual map. Ports cease to be treated primarily as endpoints. They become interfaces between terrestrial, inland-water and maritime circulation systems.

For island economies, the same principle is even more consequential. Short-sea and regional maritime services can position islands not merely as endpoints of maritime supply chains but, where economics support it, as nodes connecting continental gateways, regional production systems, logistics services and wider ocean networks. [P]

19A. The Water Corridor Commercial Test

A proposed inland-water or short-sea service should not advance from geographic possibility to infrastructure proposition until at least seven questions can be answered:

Cargo , What moves, in what volume, form, direction and season? Service , What frequency and reliability does the market require? Fleet , What vessel type, capacity, utilisation and operating economics are required? Interface , What does loading, unloading, storage and modal transfer add to cost and time? Access , How does cargo reach and leave the water system? Backhaul , What productive return flow exists? Productive Yield , What additional productive capability and retained value become possible because the water service exists?

The first six establish whether the service can function. The seventh asks whether it contributes to the economic transformation this monograph seeks.

20. Freight form and the changing physical economy

As industrialisation deepens, freight changes form: bulk becomes intermediate material; intermediate material becomes components; components become palletised, packaged, containerised or finished products; and more value may become attached to each unit of mass or volume. Each transition changes handling, storage, insurance, inventory and reliability requirements.

This freight-form transition is why tonnes cannot remain the sole language of system performance.

The same tonne can impose radically different requirements depending on whether it is ore, food ingredient, textile input, machinery component or finished consumer product.

21. Air cargo and pipelines belong in the modal universe

A 'right mode' framework is incomplete if it treats freight as only road, rail, water and sea. Air cargo is economically rational for low-weight, high-value, perishable and time-critical freight: flowers, pharmaceuticals, electronics, fashion, urgent spares and express parcels. Ethiopian Cargo reported in March 2026 that it served more than 145 destinations through freighters and belly capacity, illustrating the scale of air logistics within the African freight system. [SR]

Pipelines are also a freight mode for specific commodities: crude oil, petroleum products, gas and, in some systems, slurries. They are not a general substitute for trucking or rail, but they belong in the allocation test wherever the cargo is continuous, homogeneous and compatible with fixed infrastructure. [P] [SR; N41]

Pipeline inclusion is a modal-design proposition rather than a claim of universal suitability. [P]

THE AFRICAN METROPOLITAN CIRCULATION SYSTEM

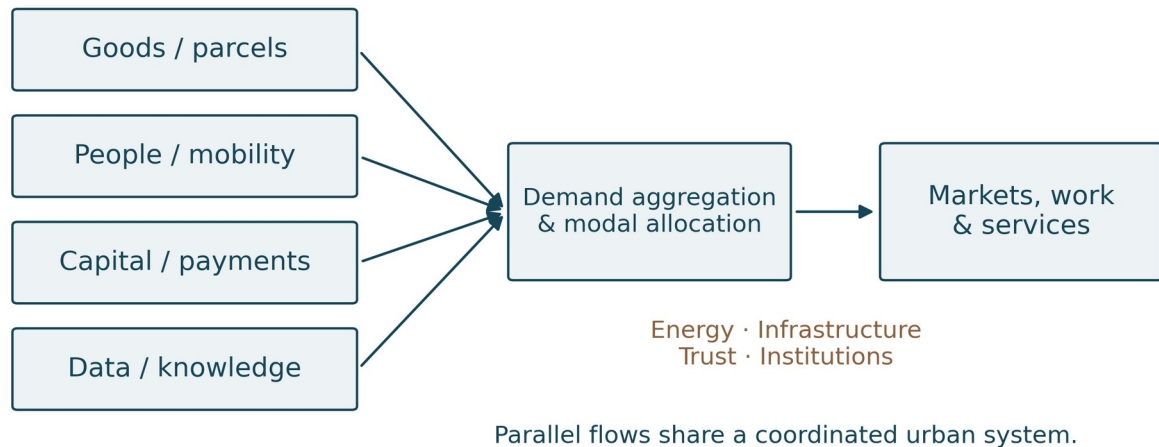


Figure 7. African Metropolitan Circulation System

Urban logistics, mobility, digital commerce and productive access The metropolitan economy is where the circulation of goods, people, money, services, information and energy becomes most visible and most contested. Roads, rail, curb space, markets, neighbourhoods, digital platforms, payment systems and public space are interfaces through which economic and social life is organised. The objective is not maximum movement. It is greater access, productive interaction and circulation of value with progressively less unnecessary transport work, congestion and energy intensity. [P]

22. Begin with the African metropolitan economy: the city as a circulation system

African metropolitan systems should be designed from the identity of the economy they serve rather than from the technology available to them. Many African cities combine formal and informal enterprise, physical markets and platform commerce, mobile money and cash, walking and motorcycles, minibuses and formal mass transit, neighbourhood retail and large supermarkets, social commerce and conventional e-commerce. These combinations are not transitional noise to be designed away. They are part of the operating landscape. [P]

The AIC2030 doctrine of trade as organised circulation acquires a particularly concrete meaning in the city. Goods move through freight and parcel systems. People move between homes, jobs, markets, education, health, commerce and social spaces. Capital and money circulate through payments, credit, investment and working capital. Information and knowledge coordinate demand and capability. Energy enables the physical economy. Trust allows digital, commercial and institutional relationships to scale. [P]

The design sequence should therefore be: understand how people trade, move, pay, work and socialise; identify the actual frictions; define the architecture; then determine which technologies can

improve it. Do not digitise dysfunction. Re-architect the system first, then digitise the architecture. [P]

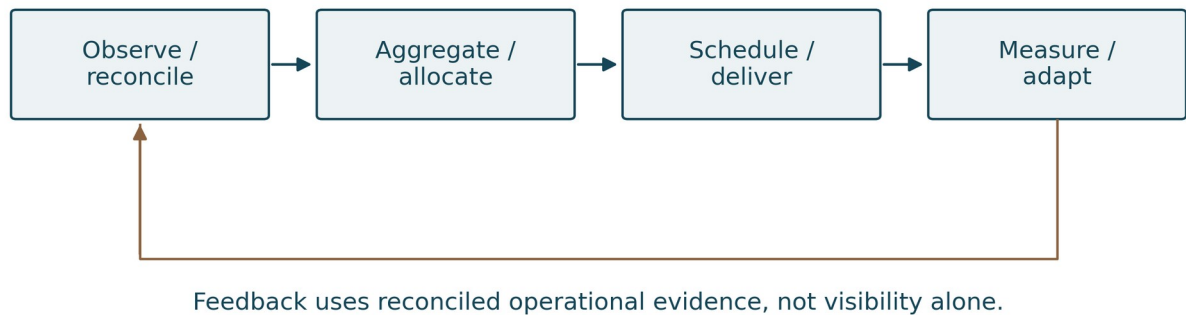


Figure 8. Data and Digital Systems for Movement

23. Urban logistics architecture: gateway, consolidation, market and neighbourhood

African freight does not end at the metropolitan boundary. Cities are where imports are distributed, food is aggregated and sold, construction materials are consumed, factories receive inputs, e-commerce orders are fulfilled, waste is removed and households gain access to goods.

Urban logistics is therefore not a final-mile appendix to corridor strategy; it is the system through which freight becomes economically useful.

A productive urban logistics architecture can be read through metropolitan gateways and ring interfaces; logistics parks and consolidation centres; wholesale and food-market systems; microfulfilment and neighbourhood distribution; curb, loading and access management; and the digital layer that coordinates orders, routing, inventory, access windows and proof of delivery. Long-haul freight should not automatically penetrate dense urban cores. Where economics justify it, heavy flows can be staged, consolidated or transferred before redistribution by vehicles and service patterns suited to the city. [P]

Gateway cities intensify the challenge because transit cargo, port traffic and local distribution share the same territory. Truck staging, appointment systems, rail interfaces, market access, bypasses, parking, land-use controls and local logistics participation should therefore be treated as one port-city operating problem, not as isolated projects.

24. Last-mile networks and Courier, Express and Parcel

The last mile is not primarily a vehicle problem; it is a network-design problem. Delivery cost, reliability, energy and carbon depend on stop density, parcel consolidation, inventory location, failed deliveries, curb access, vehicle size, route predictability, customer time windows and the distance between fulfilment points and demand. [P]

The expansion of Courier, Express and Parcel activity changes the unit economics of urban freight from fewer larger consignments toward more small consignments, higher stop density and stronger expectations around speed and visibility. Micro-fulfilment, parcel lockers, pickup points,

neighbourhood depots and shared consolidation can reduce repeated journeys where demand density supports them, but every additional node also adds rent, handling and inventory cost.

25. African digital and social commerce

African digital commerce should not be modelled only on large marketplace platforms. GSMA survey research across six African markets found that a majority of surveyed MSMEs using e-commerce sold exclusively through social-media services rather than websites or formal marketplaces, often informally. A WhatsApp or social-media order may be digitally initiated but still requires payment, pickup, consolidation, delivery, returns and sometimes wallet or cash reconciliation. Social commerce therefore creates physical logistics. [E] [N13]

26. Passenger and freight trunk systems

Urban freight and passenger mobility compete for the same road space, curb, junctions, land and time. The correct urban question is not freight versus mobility. It is how the city allocates scarce space and capacity among the movement of people, the movement of goods and the productive and social activities both movements serve. [P]

Dense, predictable movement should be carried by high-capacity trunk systems where geography and economics support them: commuter rail, metro, light rail, BRT and other high-capacity public transport for people; rail, consolidated road, water or other suitable trunk systems for goods.

Demand becomes more fragmented toward origins and destinations, where flexibility matters more. The metropolitan principle is therefore: fixed where demand is dense; flexible where demand fragments. [P]

Passenger journeys can combine walking, cycling, taxis, motorcycles and demand-responsive vans or minibuses with fixed trunk systems. Parcel journeys can combine merchant pickup, consolidation, scheduled or high-capacity transfer, neighbourhood micro-hubs and flexible last mile. Demand-responsive mobility should complement rather than cannibalise well-used mass transit; otherwise many small on-demand vehicles can worsen congestion.

27. Informal enterprise, electronic money and participation

A large share of urban distribution and mobility in African cities is performed by small enterprises and informal workers: market traders, motorcycle and three-wheeler operators, minibus owners, handcart users, informal wholesalers, micro-distributors and independent couriers. Planning them out of the system does not eliminate the demand they serve; it often pushes the activity into more dangerous or inefficient conditions.

Urban logistics reform should distinguish unsafe or obstructive practices from the economic function being performed. Formalisation, designated loading areas, safer equipment, digital payments, cooperative consolidation, access to finance and better market infrastructure can improve productivity without assuming that every urban freight activity must be absorbed by large formal operators.

Mobile money and digital wallets are also changing the meaning of financial participation. The historical distinction between 'banked' and 'unbanked' is increasingly incomplete: a person without a conventional bank relationship may still receive income, store and transfer value, pay merchants, purchase transport, participate in digital commerce and build a transaction history through mobile money. World Bank Global Findex work identifies mobile-money adoption as a major driver of financial inclusion in Sub-Saharan Africa. [E] [N14]

For the metropolitan system, electronic money is more than a payment mechanism. Permissioned transaction and service histories can support settlement, trust, business continuity and, potentially, access to finance, insurance, leasing and simpler compliance. The objective should not be surveillance or taxation by default. The progression should begin with visibility, build trust, widen access, support participation and lead to simpler compliance. Visibility should not become extraction. [P]

28. Metropolitan Movement Intelligence

Metropolitan Movement Intelligence is the capacity of a city to see, aggregate and intelligently allocate demand for the movement of people, parcels and goods across available transport assets and infrastructure. The key operational change places intelligence between demand and movement: make demand visible, aggregate it, allocate capacity and organise movement. [P] Fragmented ownership does not have to mean fragmented mobility. African metropolitan economies already contain large pools of independently owned taxis, motorcycles, minibuses, vans, trucks and courier capacity. A metropolitan digital exchange could allow authorised operators, fleet owners, cooperatives, public transport systems, CEP operators and private platforms to expose available capacity and receive compatible demand through common standards. [P]

The municipality or metropolitan authority need not become a public-sector competitor to every ride-hailing or delivery platform. Its stronger role is to govern the rails of the market: safety, identity, interoperability, competition, curb and station access, data rules, payment interfaces, accessibility and public-interest performance. Public rails, competitive services. [P]

Passenger mobility and CEP logistics have different safety, service and handling requirements, but can share a network architecture. Flexible first-mile services connect distributed origins to consolidation or interchange, a high-capacity trunk and a distribution node. Flexible last-mile services then reach distributed destinations. [P]

This creates opportunities for shared infrastructure even when passengers and parcels do not share the same vehicle. Rail or BRT stations can incorporate parcel lockers, pickup points and local delivery staging. Mobility hubs can provide passenger transfer, bicycle access, taxi and minibus zones and micro-logistics facilities. Off-peak capacity may support selected light-parcel movements where operations, safety and economics justify it. These possibilities should be tested rather than assumed. [R]

29. Movement Productivity and transaction density

Congestion should be understood partly as an allocation and utilisation problem, not only as a shortage of road infrastructure. A city can increase economic activity while reducing vehicle-kilometres per transaction if demand is aggregated, loads are consolidated, high-capacity modes carry dense flows and first/last-mile distances are shortened. [P]

The objective is not to reduce movement for its own sake. It is to increase transaction density, access and productive interaction while reducing unnecessary transport work. Delivery density, passenger occupancy, vehicle utilisation, empty running, trip chaining and return loads become strategic variables. Digital visibility enables aggregation; aggregation creates density; density enables consolidation; consolidation can reduce unnecessary vehicle movement, energy use and congestion. [P]

A useful metropolitan performance concept is Movement Productivity: people, parcels, goods and economic transactions successfully served relative to vehicle-kilometres, time, road or curb space and energy consumed. This is a proposition for measurement, not yet a standardised indicator. [P]

30. Human power, assistance and active mobility

Not every movement requires additional motorised energy. For short distances and suitable loads, walking, bicycles and cargo bicycles can perform useful passenger and delivery functions with very low operational energy demand. Electrical assistance can extend range or payload where terrain, distance or load requires it; motorcycles, three-wheelers, vans, buses and trucks become appropriate as speed, capacity and distance increase. The principle is to use human power where sufficient, add assistance where useful and motorise where the task genuinely requires it. [P]

This approach is consistent with the Pan-African Action Plan for Active Mobility and the African Union's Continental Framework on Electric Mobility, both endorsed by African transport and energy ministers on 30 April 2026. The significance for this monograph is not that one technology should dominate, but that active and electric mobility can be planned as complementary layers in an African-specific movement architecture. [E] [N16]

31. Food, markets, curb and the time dimension of urban logistics

Food logistics exposes the relationship among freight, energy and public welfare. Produce may pass through aggregation centres, wholesale markets, cold rooms, processors and neighbourhood retailers before reaching households. Poorly located markets, weak cold chains, unreliable electricity and traffic restrictions that ignore delivery windows can convert agricultural output into loss, congestion and higher consumer prices.

The curb is freight infrastructure. Loading, ride-hailing, buses, parking, informal trade, pedestrians, waste collection and service vehicles compete for the same street edge. Delivery bays, time windows, digital booking, enforcement, market loading areas, pricing and shared-use rules can increase the productive capacity of existing streets without widening them. The correct design will vary by district. [P]

32. Functional density, land use and the human city

Urban mobility should ultimately be judged by access: whether people can reach jobs, markets, services and opportunities, and whether goods can reach households and firms reliably. Transit-oriented development, wholesale markets, logistics nodes, industrial areas and residential growth should therefore not be planned as independent maps. Poor land-use decisions can create transport demand that infrastructure is then forced to absorb.

The hierarchy of human-powered, assisted and motorised movement does not imply a city of reduced interaction. Offices, supermarkets, hardware markets, schools, clinics, restaurants, worship spaces, workshops, wholesale markets and public spaces continue to generate valuable movement and social exchange. The objective is not immobility. It is to distinguish productive and socially valuable movement from avoidable movement created by poor land use, empty running, fragmented deliveries and weak coordination. [P]

Functional density matters as much as population density. When employment, services, commerce, transit, markets, fulfilment and public space are located so that people can reach opportunity with shorter or higher-capacity journeys, the city can support more economic and social interaction with less transport work.

33. Urban energy, performance and governance

Urban and last-mile operations are among the freight applications where electrification can be attractive because routes are shorter, utilisation can be high and charging can often be depot-based or organised around predictable duty cycles. Two- and three-wheelers, delivery vans, terminal tractors and selected municipal or service fleets can become early candidates where electricity supply, asset finance, maintenance and charging economics work. Technology should follow duty cycle and system economics.

Last-mile fleet transition should assess safety, worker conditions, charging or battery swapping, asset finance and opportunities for local assembly alongside duty cycle and system economics. The transition should strengthen the productive ecosystem that operates, maintains and supports the fleet.

Urban logistics parks, wholesale markets, fleet depots, consolidation centres and large fulfilment facilities can become metropolitan freight-energy nodes where delivery fleets, cold-chain loads and logistics facilities create concentrated, predictable demand. Energy therefore follows the movement architecture rather than preceding it as a generic technology target. [P]

Urban performance should be measured through delivery reliability, vehicle-kilometres per delivery, load factor, empty running, curb dwell, failed-delivery rate, loading and access queues, logistics cost as a share of delivered value, energy per delivery, emissions per delivery, market and cold-chain losses and the productivity of logistics land. Governance must orchestrate city roads, national highways, ports, police, market agencies, land-use departments, public-transport authorities, environmental regulators and private operators rather than simply create another freight authority.

A practical urban freight programme should establish a shared baseline, identify priority interfaces, agree which institutions control each lever, run targeted demonstrations and measure the results. Port-city interface labs, urban freight forums, delivery-window pilots, market-access reforms and consolidation demonstrations should address specific operational problems with accountable implementation counterparts. These interventions should follow the implementation sequence set out in Part X.

POWERING THE PHYSICAL ECONOMY

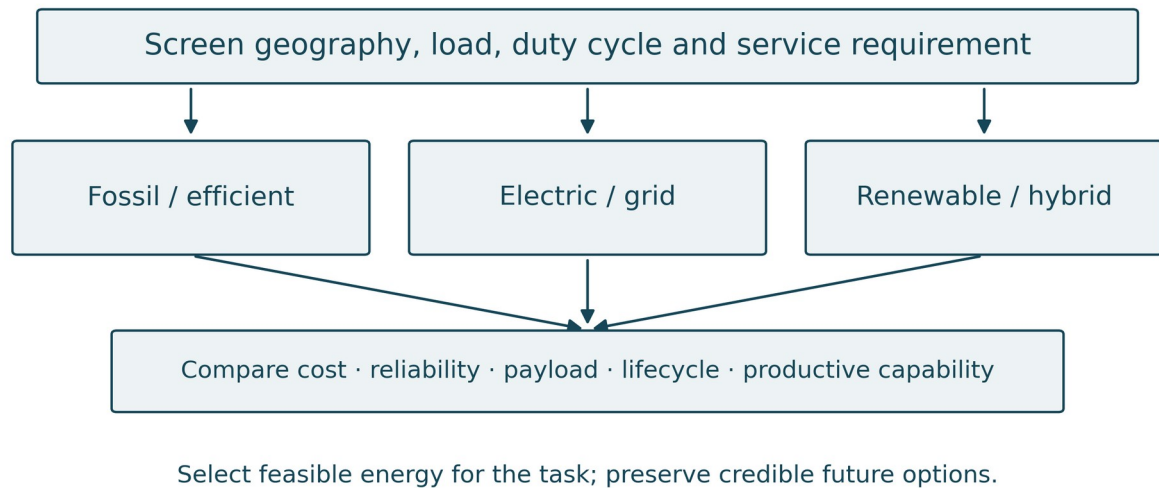


Figure 9. Energy Allocation to Movement

Energy Allocation and Network Sequencing

Gas can be important where lifecycle performance, economics and reliability justify it - including selected electricity, industrial heat, fertiliser, petrochemical or transport applications - but it is not carbon-free and should not be labelled a universal transition fuel. Oil likewise requires productive-use discipline, efficiency and declining waste.

A progressive energy network links gateway supply, inland logistics, border and metropolitan nodes, and last-mile fleets. Chapter IV tests this sequence against geography and offtake rather than assuming one technology across every route.

Decision dimension Question What grid, storage, bunkering, charging or fuel system is Infrastructure required? Can the technology perform the required operation without Range / duty cycle distorting service? Payload What payload or capacity penalty applies? Reliability Can the energy system support required service availability? Carbon What is the operational carbon profile? Lifecycle What are the upstream, embodied and replacement implications? Scalability Can supply, maintenance and infrastructure scale with demand? What African capability, value retention and enterprise Productive Yield opportunity result? The Productive Energy Allocation Matrix should be preceded by a geography-and-demand screen: local energy resource; distance to demand; load profile; offtaker creditworthiness; modular versus permanent infrastructure requirement; connection cost; and transition-dependency risk. Technology comparison begins only after this screen establishes the operating context.

34. Africa's energy-development challenge

Africa cannot industrialise on an energy-scarcity doctrine. Households, schools, hospitals and cities need dependable electricity. So do mines, factories, cold chains, data centres, ports, railways and logistics platforms. The continent therefore faces an energy-development challenge and a decarbonisation challenge at the same time.

The correct sequence is energy abundance, diversification, intelligent allocation, productive use, efficiency and progressive decarbonisation. This does not mean that every energy source should expand everywhere. It means that energy decisions must be evaluated against reliability, affordability, scalability, productive usefulness, security, lifecycle impact, infrastructure requirements and technological maturity.

Energy for people and production must be treated together. Households, schools, hospitals and cities need dependable electricity; so do mines, factories, cold chains, logistics platforms, digital systems and industrial heat. A freight-energy transition that weakens either human access or productive capability is incomplete. [P]

35. Fossil-Smart, Energy-Diverse, Future-Ready

Fossil-Smart means eliminating fossil waste and making necessary residual fossil use measured, efficient and disciplined while reducing lifecycle intensity. Energy-Diverse means matching energy sources to geography, demand, duty cycle and reliable service. Future-Ready means designing assets and infrastructure to preserve viable options as cleaner technologies, fuels and energy systems mature. [P]

The transition test also includes upstream methane, gas supply and safety, fossil lock-in, stranded-asset risk and the credible availability of alternatives. Productive use of existing resources is not a licence to disregard lifecycle emissions or to prolong an uneconomic dependency. [P]

Oil and gas remain part of African energy systems and, in some countries, part of their resource base and industrial opportunity. A credible transition should neither romanticise fossil dependence nor pretend that existing energy realities disappear through declaration. The first discipline is to eliminate fossil waste: idling, empty running, inefficient generators, avoidable congestion, poor process heat, inefficient port equipment and infrastructure that locks in unnecessary consumption.

Gas can be important where lifecycle performance, economics and reliability justify it, including selected electricity, industrial heat, fertiliser, petrochemical or transport applications, but it is not carbon-free and should not be labelled a universal transition fuel. Oil likewise requires productive-use discipline, efficiency and declining waste.

Renewables, storage and electrification can be powerful where duty cycles and grids support them.

Solar should be evaluated with land opportunity cost, resource quality, grid connection, storage, water, financing and industrial proximity in view. Battery systems are well suited to many port and urban applications, but long-haul freight requires payload, charging, range and utilisation analysis.

Methanol, hydrogen-derived fuels, ammonia and sustainable biofuels may become important in specific applications, particularly maritime, but infrastructure, safety, supply and lifecycle economics remain decisive.

Not one energy source for everything, but the right energy source for the right productive application.

Oil productive-use discipline is therefore part of the transition: where liquid fuels remain necessary, the priority is to reduce idling, empty running, inefficient equipment and avoidable fuel burn while progressively shifting applications when credible alternatives become economically and operationally superior. [P]

The Fossil-Smart discipline spans all five maturity stages; Stage 3 demonstrates disciplined residual fossil use (Tables 19 and 33). [P]

36. Intelligent Energy Allocation

The energy question should therefore be treated like the modal question. For each application, compare capital cost, operating cost, energy availability, infrastructure, range, payload, reliability, lifecycle carbon, scalability, energy security and African Productive Yield. A port tractor, an urban delivery van, a long-haul truck, a locomotive, a river barge and an ocean vessel do not need the same answer.

37. Where freight energy demand sits

Freight energy should be planned geographically, not only technologically. The relevant questions are: where is freight-energy demand concentrated; what energy resources exist within or near that geography; how reliable are they; what conversion or transport infrastructure is required; and which productive users can underwrite the system? This creates a spatial relationship between energy source, conversion, energy node, freight application and productive demand. [P]

The implication is important for African freight. A national energy mix does not by itself determine the energy architecture of a port, mining corridor, urban delivery system, lake service or industrial logistics cluster. The same technology can be appropriate in one operating geography and uneconomic in another. Freight decarbonisation architecture should therefore follow cargo economics, operating geography, energy availability and credible demand rather than technology fashion.

38. Recovering wasted and stranded energy

Before importing additional energy into a freight or industrial system, planners should identify energy that is being wasted, stranded or underutilised within the productive geography. Associated gas that would otherwise be flared is one example; other forms require their own technical and lifecycle assessment. Aggreko's 2026 From Flare to Value briefing discusses commercial configurations for converting associated gas into productive power, but it is used here only as an architectural analogue for energy recovery, offtake and modularity - not as evidence that gas is the preferred freight fuel. [SR] The publisher's announcement confirms the briefing; route-specific performance still requires technical and lifecycle evidence. [N12]

39. Freight energy nodes

African freight-energy transition need not wait for a complete nationwide charging, fuelling or alternative-energy network. Concentrated freight nodes can become early energy anchors: ports, logistics parks, truck terminals, border facilities, dry ports and ICDs, SEZs, industrial parks, fleet depots, wholesale markets and major metropolitan distribution nodes.

A node-first architecture allows energy infrastructure to grow around predictable duty cycles and credible demand. One node may initially combine grid power, solar, storage and efficient backup; another may justify fleet charging, shore-power readiness, cleaner fuels or other energy systems.

The technology is secondary to the operating case.

The long-term network can emerge progressively, connecting gateway energy nodes, inland logistics nodes, border or corridor nodes, metropolitan distribution nodes and last-mile fleet systems. This is more consistent with African infrastructure sequencing than assuming one uniform energy technology across every route from the outset.

40. Build energy around credible demand

Freight-energy infrastructure should begin with demand, not equipment. The central commercial question is: where does sufficiently concentrated, predictable and creditworthy energy demand already exist? Ports, mines, industrial parks, cold chains, fleet depots, logistics platforms and large distribution centres can provide the load profile that makes investment possible. [P]

The energy-design sequence should therefore ask: who consumes the energy; how much and when; how predictable is the load; what service reliability is required; what price can be supported; what contract underwrites demand; and what happens if utilisation is lower than expected? This connects Productive Energy directly to Bankability Discipline.

41. Transitional energy logistics

Energy infrastructure does not always have to precede demand through permanent networks.

Temporary or modular arrangements can connect energy supply to productive freight demand while fixed grids, pipelines, charging or fuelling networks develop. The principle should be tested against safety, cost, lifecycle emissions, utilisation, lock-in and the point at which permanent infrastructure becomes economically superior. [P]

42. Future-Ready: optionality, modularity, scalability and relocatability

Future-Ready infrastructure should protect more than technological optionality. Where the asset class permits it, modularity, scalability and relocatability can reduce the risk of building permanent capacity ahead of uncertain demand. Containerised or modular generation, storage, charging or fuel-handling systems can sometimes expand with demand or be redeployed if the operating geography changes.

This principle should not be forced onto infrastructure that requires permanence. Railways, ports and core grids are not temporary systems. The design question is instead which layers should be fixed for long-term capacity and which can remain modular while demand, technology and energy supply mature.

43. Ports as energy nodes

Ports sit at the intersection of vessels, cargo-handling equipment, trucks, rail, warehouses, cold chains and industrial activity. They are therefore natural energy nodes. Solar and storage, equipment electrification, shore power, efficient lighting and buildings, future-fuel readiness and digital energy management can be coordinated as a system rather than installed as isolated projects.

Future-ready infrastructure is infrastructure with optionality. Quays, power connections, logistics parks, rail terminals and industrial zones should be designed so that future technologies can be adopted without paying twice for avoidable reconstruction.

The port can therefore be understood as a multi-energy gateway. It concentrates ships, trucks, cargo-handling equipment, reefer demand, warehouses, logistics parks, industrial activity, rail in some locations, bunkering and digital trade information. This makes it one of the most credible locations for phased energy transition because multiple users can share infrastructure and create an aggregated demand base.

A future African gateway can increasingly combine four functions: Cargo Gateway + Energy Gateway + Industrial Gateway + Data Gateway. The value lies in the interaction among them.

Energy supports freight and industry; cargo volume can underwrite energy investment; industrial users create stable demand; and data coordinates assets, carbon information, scheduling and commercial settlement.

44. Three layers of carbon

Operational carbon comes from vehicles, vessels, equipment and energy. Grey or embodied carbon is locked into cement, steel, asphalt, buildings and replacement cycles. System carbon arises from the architecture itself: unnecessary kilometres, congestion, empty running, waiting and poor spatial design. A freight transition that measures only tailpipe emissions can therefore miss major sources of carbon and cost.

System-induced carbon is an attribution and diagnostic view of operational emissions caused by congestion, empty running, waiting and spatial design; it is not a third additive inventory. Report each emission source once within a declared boundary. Embodied and operational emissions may be combined only across compatible lifecycle periods, with transparent allocation and no double counting. [P]

Every major capital proposal should compare whole-life carbon and cost across construction, operation, maintenance, replacement and end of life for an equivalent service. Materials passports should retain quantities, origin, declared emission factors or verified product declarations, provenance, reused content and recovery options. Compare refurbishment and reuse with new construction. Asset-level assessment must replace universal assumptions about embodied-carbon shares. Annex F specifies the procurement and baseline protocol. [P]

45. Productive Energy architecture

The complete energy layer comprises: Clean Fossil Systems; Energy Efficiency & Logistics Optimisation; Renewable & Hybrid Integration; Digital Carbon Intelligence; Grey Carbon & Circular Infrastructure; and Transition Finance & Carbon Capital. Clean Fossil Systems include efficient engines and generation, cleaner fuel specifications where appropriate, hybrid equipment, efficient backup generation, industrial fuel switching and operational discipline. Efficiency covers gates, staging, routing, scheduling, empty returns, audits, retrofits, dwell and telematics. Renewable and Hybrid Integration combines locally appropriate renewables, storage, grid systems and reliable backup. Digital Carbon Intelligence connects telematics, MRV, dashboards and decision-grade emissions data. Grey Carbon addresses materials, construction and circularity. Transition Finance matches capital to verified outcomes rather than labels.

46. Energy security, hybrid systems and spatial opportunity cost

Energy availability, reliability and price directly affect freight reliability. Ports cannot electrify equipment if power is unreliable. Cold chains cannot protect food if electricity fails. Rail electrification cannot outperform diesel if supply is unstable. Industrial zones cannot deepen transformation if firms maintain costly backup generation. Energy security therefore belongs inside freight economics.

Hybridisation can be an economically rational architecture: grid + solar + storage + efficient backup; diesel-electric or battery-hybrid equipment; renewable power supplemented by firm generation; port microgrids combining several sources. The correct measure is system performance across reliability, cost, lifecycle carbon and productive use.

Renewable energy is not land-neutral. Utility solar can compete with agriculture, biodiversity, settlement or future industrial land if badly located. Equatorial geography does not automatically make solar expensive; irradiance, temperature, cloud cover, financing, grid connection and storage determine economics. Rooftops, logistics parks, parking structures, degraded land, infrastructure corridors and agrivoltaics can reduce land conflict.

47. Battery and technology sovereignty

The Green Extraction Trap becomes especially visible in batteries. An extractive transition can export African minerals, import refined materials and cells, import finished electric equipment and leave the continent as a demand market for technologies built from its own resource base. The alternative is selective capability building across critical-mineral refining, active materials where viable, modules and packs, electrical systems, charging, energy management, maintenance, second-life storage and recycling.

Every major transition technology should face a local-value-addition test: what can African firms realistically manufacture, assemble, install, operate, maintain, finance, software-enable, repair or recycle? It should also face a dependency test: does the technology create new exposure to imported equipment, proprietary systems, critical components, external finance or scarce skills?

48. Asset decarbonisation versus system decarbonisation

Freight decarbonisation operates at two different levels. Asset decarbonisation asks how to make the truck, locomotive, vessel, crane, warehouse or terminal cleaner through fuels, electrification, efficiency, renewable power or improved equipment. System decarbonisation asks why the movement exists, whether it is necessary, whether another mode should perform it, whether interfaces can be redesigned, whether waiting and empty running can be removed, and whether production, storage and logistics nodes are located intelligently.

Both are necessary, but they solve different problems. A cleaner truck still wastes energy if it travels unnecessary kilometres, returns empty or waits for hours at an interface. A low-carbon vessel can still participate in an economically extractive system. The first frontier is therefore to eliminate avoidable system waste and then clean the assets required for the movement that remains.

MARKET POWER, REGULATION AND THE POLITICAL ECONOMY OF FREIGHT

49. Carrier, terminal and logistics power

Freight outcomes are shaped not only by infrastructure but by who controls capacity, terminals, inland services, data and commercial relationships. UNCTAD's Review of Maritime Transport 2025 shows that the global liner market remains highly concentrated: MSC alone held about 20% of global liner shipping capacity in TEU terms in April 2025, while alliance restructuring continued to shape capacity deployment and service networks. Major carriers also continue to extend their presence across terminals and logistics. [E] [N28]

The policy question is therefore not simply whether a port has capacity. It is whether shippers face sufficient contestability, transparent access and bargaining power across ocean services, terminals and inland logistics. Market structure can affect freight rates, service frequency, terminal choice and the ability of public authorities to shape gateway strategy. [SR; N28]

50. Concessions, third-party access and infrastructure rights

Who can use infrastructure, on what terms and at what tariff can matter as much as the physical asset. South Africa's freight-rail reform illustrates the point: on 13 May 2026, the Transnet Rail Infrastructure Manager announced 11 Train Operating Companies allocated slots on the national rail network across five strategic corridors. The allocations were expected to add about 24 million tonnes of freight capacity; operating start dates differ by operator and should be treated as implementation reporting rather than as one universal commencement date. [SR] [N8]

For corridor analysis, rail viability should therefore include access regime, network tariff, path allocation, infrastructure-manager performance and terminal rights. A theoretical modal advantage can remain inaccessible if the institutional access regime does not permit viable service. [SR; N8]

Allocations are programme commitments; current access agreements and actual commencement require verification before an investment decision. [R]

51. Cabotage and the legal architecture of short-sea shipping

Short-sea shipping is partly a legal and regulatory proposition. ECOWAS called in July 2025 for accelerated preparation and implementation of a regional cabotage regime to support the Praia-Dakar maritime link and other West African regional maritime services. [E] [N9]

The Abidjan-Lagos short-sea case must therefore test cabotage rights, vessel registration, customs and transit treatment, port dues, crew rules, service licensing and competition conditions alongside vessel economics and cargo density. [SR; N9]

52. Informal rents, checkpoints, transit bonds, FX and security

Political economy is not a residual issue in freight. Checkpoints, informal payments, overloading incentives, transit guarantees, customs discretion, foreign-exchange shortages, cargo theft and maritime insecurity can materially change route economics.

The World Bank's June 2026 Douala-Bangui programme illustrates the scale such frictions can reach: it reported transport costs as high as US\$270 per tonne, normal journey times of 9-12 days and 38 checkpoints in Cameroon alone, 17 involving informal payments. [E] The implication is not that every African corridor has the same problem, but that an infrastructure-only diagnostic can miss the incentives that preserve delay. [N10] [SR; N10]

53. Carbon regulation is becoming trade architecture

Carbon information is increasingly connected to market access. The EU's Carbon Border Adjustment Mechanism entered its definitive regime on 1 January 2026 and initially covers cement, iron and steel, aluminium, fertilisers, electricity and hydrogen. Importers must address embedded emissions through the CBAM system. [E] [N3]

Maritime trade is also exposed to regulatory carbon pricing and fuel-intensity rules. The EU ETS has covered CO₂ from large ships calling at EU ports since 2024 and includes methane and nitrous oxide from 2026; FuelEU Maritime has applied from 2025 and progressively lowers the permitted well-to-wake GHG intensity of energy used on covered ships. [E] [N11]

These rules do not make a proprietary 'Carbon Passport' mandatory. They do make credible, interoperable and verifiable carbon data commercially more consequential. The Carbon Passport proposition in this monograph should therefore be understood as a potential African data and market access layer built on recognised accounting standards, not as a substitute for them. [P] [E; N3; N11]

The proposed record should use ISO 14083 and the GLEC Framework for transport-chain emissions accounting, while mapping relevant data to the separate requirements of each applicable regulatory regime. Transport-chain accounting does not by itself establish CBAM product-emissions compliance or FuelEU Maritime compliance for energy used on board ships. The record should retain accounting boundaries, units, allocation methods, emission factors, source versions and verification status, allowing users to trace how reported figures were derived. Authorised reuse of verified data should reduce duplicate reporting; the Carbon Passport should not introduce a parallel certification obligation or an additional mandatory administrative fee. [P; N2; N3; N11]

54. AfCFTA as a freight-system driver

AfCFTA matters to freight not only because it can increase trade volumes. It can change production geography, rules-of-origin incentives, distribution networks, border processes, warehousing requirements and the economics of regional services. The physical market must therefore develop alongside the legal market. [P]

This monograph treats AfCFTA as a demand-and-architecture driver rather than a stand-alone trade statistic.

Applied to market access, the Resource-to-Market chain defined in Chapter I requires a further test after delivery: whether revenue and capability remain in the productive economy and are reinvested so that productive capacity compounds over time. The complete eight-stage chain is retained in Figure 3 and the Chapter I definition.

PRODUCTIVE TRANSFORMATION, CAPITAL AND SYSTEM GOVERNANCE

Enterprise and Capital Transmission Logic

Enterprise graduation is a central link between freight and productive transformation. The supplier progression in topic 56 tests who participates in freight-created markets and who retains their value. [P]

The capital system must support the full productive chain. Topic 60 traces infrastructure finance through industrial investment, equipment, trade and working capital into enterprise growth and reinvestment. [P]

55. The Green Extraction Trap

Africa can decarbonise its logistics while reproducing the economic structure it is trying to escape.

Critical minerals can be exported in low-value forms, transformed elsewhere into batteries and equipment, and then re-imported as the technologies used to green African transport. The carbon profile may improve while productive dependence deepens.

The strategic question is therefore whether the freight-energy transition can build African capability in selected parts of the value chain: refining and materials, packs and modules, charging systems, electrical equipment, alternative fuels, engineering, software, maintenance, second-life applications and recycling. The objective is not to manufacture everything domestically. It is to identify where local and regional capability is economically defensible and strategically valuable.

56. Decarbonisation as industrialisation

A transition programme becomes an industrialisation programme when investment in lowercarbon systems creates productive assets, skills, suppliers and enterprises. Port electrification can create demand for electrical engineering and maintenance. Rail rehabilitation can support fabrication and systems capability. Cold-chain expansion can stimulate equipment, energy and service markets. Alternative maritime fuels can connect energy production to bunkering, storage and port services. [P]

This is why procurement matters. So do standards, finance, supplier development, skills and research institutions. A corridor that imports every technology as a finished package may become cleaner without becoming more capable.

57. Enterprise graduation and knowledge infrastructure

Productive transformation must become visible in firms. Informal enterprises can progress into formal enterprises, reliable suppliers, contract-ready companies, industrial suppliers, regional value-chain participants and exporters or investors. Freight systems create markets for trucking, barging, warehousing, software, maintenance, energy, packaging, cold-chain services, terminals and industrial supply; who captures those markets shapes how much value remains in the economy. [P]

Engineers, technicians, mariners, logistics professionals, customs specialists, software developers, energy engineers, industrial managers and financiers are productive infrastructure. Universities, TVET institutions, maritime academies, research institutes and industrial training centres therefore belong inside the freight architecture. Enterprise ownership and skills must be assessed together: Productive Yield depends on whether African firms can acquire the capabilities needed to operate, maintain, finance and eventually own more of the system. [P]

Ownership and participation should be examined by layer rather than through one aggregate percentage: production, logistics, technology, finance, data, distribution, maintenance and market access may each contain different African enterprise positions. The objective is to identify where participation can deepen into durable capability and ownership without confusing nominal shareholding with productive depth. [P]

58. Cities, productive territories and return flows

Rural territories should not be treated simply as hinterlands that feed metropolitan gateways. They are productive economies. Cities, meanwhile, are not merely congestion problems; they concentrate demand, labour, knowledge, finance and services. The development question is how to connect these spaces so that goods move outward and income, capital, technology, knowledge and services move back.

A distributed productive geography can reduce unnecessary movement while strengthening secondary cities and rural transformation. But distribution must not be romanticised: some activities require metropolitan scale, specialised labour or gateway access. The system should allocate functions according to productive economics.

59. The ocean productive economy

At the coast, freight becomes part of a wider ocean productive economy: ports, coastal shipping, fisheries, marine industries, ship repair, bunkering, offshore energy, maritime services and ocean data. Blue SEZs can become industrial interfaces between ocean space, logistics, energy and production, provided they create measurable productive additionality. [P]

Short-Sea Shipping can become more than a secondary maritime service. In the right geography it can form the structural fabric of a distributed coastal economy, linking ports with differentiated roles and creating alternatives to selected long road hauls. The proposition remains conditional on cargo density, frequency, port cost, vessel economics, first/last-mile interfaces and regulatory conditions.

Clean Calls describe the progressive ability of ports to serve lower-emission vessel and cargo operations through efficient berthing, reduced waiting, cleaner equipment, shore-power readiness where demand supports it and future-fuel capability. The Energy Hub extends the port's role by coordinating grid power, renewable generation, storage, conventional fuels and emerging maritime fuels according to demand and safety.

60. Capital, bankability and risk allocation

Infrastructure alone does not create a productive freight economy. Public capital may fund enabling infrastructure; project and PPP capital may finance bankable assets; asset finance is needed for vessels, wagons, trucks and equipment; corporate and equity capital builds industrial capacity; trade finance funds inventory and cross-border commerce; working capital allows enterprises to use the infrastructure; climate and blended finance can de-risk selected transition investments.

The question is how capital moves through the corridor economy so that infrastructure investment ultimately creates productive capacity. A modern logistics platform surrounded by firms unable to finance inventory, equipment or expansion will underperform its physical design.

Every major freight, energy, industrial or digital proposition must eventually face Bankability Discipline. The questions are concrete: Who pays? Who owns? Who operates? What is the revenue model? Who carries demand risk? Who carries currency, construction, technology, regulatory and operating risk? What requires public subsidy, guarantee or concessional capital? What can support commercial capital? What happens if utilisation is lower than forecast?

Currency mismatch must be explicit where freight revenues are earned in local currency but debt service, imported equipment or energy obligations are payable in foreign currency. The financial model should identify the currency, timing and indexation of each material cash flow and state who bears each exposure. Currency depreciation, foreign-exchange liquidity shortages and restrictions on conversion or transfer are distinct risks; a profitable local-currency business may still be unable to meet foreign-currency obligations. Stress tests should cover devaluation, interest-rate increases, refinancing pressure, imported-equipment cost inflation and interrupted access to foreign currency. [P; N27]

Local-currency debt, domestic institutional investment, suitable credit enhancement and currency hedging should be assessed against their availability, cost and tenor. Hedging is not assumed to be accessible or affordable. Tariff indexation and contractual risk sharing can redistribute exposure but must be tested for user affordability, enforcement and residual risk. A project should demonstrate acceptable debt-service coverage and liquidity under the declared stress scenarios before a bankability recommendation is made. [P; N27]

This discipline separates strategic desirability from financial viability. A project can be economically valuable but not commercially bankable; it can then require an explicit public-good rationale and appropriate public or blended finance. Conversely, commercially attractive components should not automatically absorb scarce concessional capital. Bankability Discipline therefore connects system architecture to implementable capital structures.

Freight-energy transition is as much a commercial-architecture problem as a technology problem.

Every intervention should identify the asset, owner, operator, user, offtaker, revenue, risk and capital. These are connected commercial responsibilities, not an automatic causal sequence. [P] Commercial structures such as BOO, BOOT, BOOM or IPP arrangements can be useful where they fit the asset, regulatory environment and risk allocation. They are not preferred models by default.

The World Bank Group's PPP Reference Guide provides the more appropriate neutral discipline: clarify the public-service objective, ownership and management responsibilities, performance-linked remuneration, lifecycle obligations and the allocation of demand, construction, operating, currency and regulatory risks. The commercial structure should follow the economic function and risk profile rather than the technology label. [P] [N27]

For freight-energy nodes, the same discipline should be applied to charging infrastructure, storage, distributed generation, shore power, alternative-fuel systems, logistics platforms, vessels, rolling stock and fleet conversion. A technically attractive transition that lacks an offtaker, credible utilisation or a viable risk allocation is not yet an investable transition.

Capital should follow freight's end-to-end logic, connecting infrastructure finance, industrial investment, equipment finance, trade finance and working capital with enterprise growth, revenue and reinvestment. A corridor can contain high-quality infrastructure and still underperform if firms cannot finance inventory, equipment, certification or expansion. [P]

Insurance is not peripheral to freight economics. Cargo loss, road and maritime safety, climate exposure, political and border risk, infrastructure reliability and operator performance influence premiums, collateral and financing. A route that appears cheaper before reliability and risk are priced can become more expensive after the commercial risk is recognised.

61. Borders as economic architecture

Borders are not only customs checkpoints. Transit guarantees, standards, SPS systems, payments, insurance, rules of origin, trusted-operator arrangements and data interoperability determine whether a regional value chain can function. A border can connect productive economies or become a business model built around friction. [P]

62. Governance from assets to systems

Ports, railways, roads, waterways, SEZs, energy systems and cities usually have different owners and regulators. Freight crosses them all. The governance challenge is therefore not necessarily to create another institution, but to create the capacity to orchestrate flows, investment, land use, industrial development, energy, data and markets across institutional boundaries.

Industrial policy, freight policy, energy policy, trade policy and land-use planning should not be designed as separate maps. Industrial location changes freight. Energy location changes industrial viability. Logistics parks consume land. Ports compete with cities. Renewable energy infrastructure can compete with agriculture or urban expansion.

Spatial opportunity cost should therefore be explicit in major infrastructure decisions. The relevant question is not only whether an asset fits physically, but what alternative productive use of land, capital, energy or institutional attention is displaced by the choice.

System orchestration is the governance task that connects separately owned and regulated assets around shared productive outcomes. It does not require one institution to own the corridor; it requires interfaces, incentives, accountability and decision rights to be sufficiently coherent for the system to function. [P]

63. Digital systems, interoperability and data sovereignty

Corridor Intelligence combines cargo, customs, trade, transit, production, energy, market, investment and enterprise data to answer economic questions: where is value leaking; where should processing locate; which freight should change mode; where is capacity underused; which market is underserved; which suppliers can graduate? Digital Carbon Intelligence is a specialised layer connecting energy and emissions data to operations, finance, market access and investment.

Port Community Systems connect port actors and cargo processes. Maritime Single Windows reduce repeated reporting and improve vessel-clearance interfaces. Corridor control towers integrate visibility across nodes and modes. Their value lies in reducing information friction and enabling coordinated decisions. Interoperability matters because isolated platforms can reproduce institutional fragmentation electronically.

Freight data increasingly influence investment, customs, carbon reporting, market access, insurance and commercial power. Data sovereignty concerns the ability of African institutions and enterprises to govern strategically important data, set access conditions, preserve security and extract economic intelligence while remaining interoperable with trade systems.

Data is an economic flow because visibility, identity, documents, payments, cargo events and performance information affect whether physical and commercial journeys can complete.

Regulatory interoperability is therefore as important as technical interoperability: standards, customs, access rules and recognised digital records must be able to interact across institutions and borders without requiring complete institutional uniformity. [P]

64. Resilience, system switches and multi-shock design

Resilience is not duplicate infrastructure. It is the capacity to substitute, reroute, adapt and recover while preserving productive function. A second port, railway or route has little resilience value if it cannot absorb cargo, lacks equipment, is disconnected from markets or cannot be activated quickly. Distributed nodes become useful only when they can function as system switches. [P]

The core measures are substitutability, available alternative capacity, recovery time, disruption playbooks and the productive consequences of failure. The proposed Modal Redundancy Factor in the technical annex is one supporting metric; recovery performance remains the more important outcome. [P]

African freight systems should be tested against multiple shocks: climate, energy, geopolitical and maritime disruption, border and regulatory interruption, cyber/data failure, financial stress, food-system shocks and loss of critical inputs or equipment. Responses can include modal and gateway alternatives, energy diversity, strategic inventory, interoperable data, financial buffers and diversified suppliers. [P]

65. The Living Corridor

Freight systems are inhabited. Worker mobility, housing, safety, community services, urban quality, environmental conditions and access to opportunity influence productivity. A system cannot be considered economically intelligent if it achieves logistics performance by externalising unsustainable costs onto the people and places through which it operates.

FOUR PRODUCTIVE-DENSITY JOURNEYS

66. Minerals • from geological weight to industrial function

A mineral corridor is the clearest example of the difference between throughput and productive value. Ore can move in very large quantities and sustain railways, roads and ports while relatively little transformation occurs between mine and ship. Concentration, refining and downstream manufacturing can alter that relationship. Waste rock and unwanted material need not always travel the full export distance; intermediate products can carry greater value per tonne; and downstream components can embed engineering, quality systems, specialised labour and supplier networks.

The economic case for beneficiation is never automatic. Energy intensity, water, scale, technology, environmental constraints, market access and transport economics can make processing at source uneconomic for particular minerals. The correct question is therefore not 'beneficiate everything'.

It is: at which stage does African transformation become commercially and strategically defensible, and what freight architecture follows from that decision?

The same discipline applies to local-content and localisation policy. Geographic proximity to a resource does not by itself create comparative advantage. Requirements that force uneconomic local production can raise costs, weaken competitiveness, delay investment or protect capability that never becomes productive. The development objective is therefore not localisation at any price. It is to retain productive value where the economics support it, build capabilities that can change those economics over time, and expose the trade-offs when strategic or resilience objectives justify a higher near-term cost. [P]

Productive Yield must not reward inefficient localisation merely because activity occurs inside the territory. A localisation proposition should still pass cost, quality, scale, energy, technology, market access and resilience tests. Where imported capability is temporarily superior, the relevant question is whether the freight and industrial architecture creates a credible pathway for learning, supplier development and competitive capability rather than permanent dependency. [P]

For freight planners, the shift can be profound. Bulk rail and conveyor systems may dominate the upstream chain. Refined materials may require different terminals and storage. Manufactured components may move in containers, at higher value density, with tighter reliability and inventory requirements. The same geological resource can therefore generate several distinct freight systems depending on how much transformation occurs before export.

67. Cotton, textiles and garments • when weight becomes complexity

Cotton makes the freight paradox visible. Raw fibre is a commodity flow. Yarn introduces industrial processing. Fabric adds another stage, and garments add design, cutting, assembly, finishing, packaging, branding and distribution. The final product may not be heavier than the raw material from which it began, yet the economic activity surrounding it can be vastly more complex.

That complexity changes logistics. Inputs and accessories must arrive reliably. Production schedules become sensitive to delay. Finished garments are often more cube-sensitive than weight-sensitive. Warehousing, consolidation, quality control, customs procedures and air or expedited freight can

become relevant. The corridor is no longer simply carrying agricultural output to a port; it is coordinating an industrial system.

This is why cubic metres, units, frequency and inventory become as important as tonnes. It is also why time becomes capital. A delayed raw cotton shipment is a logistics problem; a delayed input that stops a garment line can become a production and working-capital problem.

68. Cocoa and food processing • value, perishability and geography

Cocoa illustrates Productive Yield particularly well. An efficient export chain can move beans from farm to port while most product development, processing, branding and margin creation occur elsewhere. A productive architecture asks which additional capabilities can be built around the same flow: aggregation, traceability, quality systems, primary processing, ingredients, food manufacturing, packaging, market intelligence and enterprise development.

The correct geography may be distributed. Some first-stage transformation may belong near producing territories; more sophisticated processing may require energy, water, skills and scale available at industrial nodes; branded manufacturing may benefit from proximity to metropolitan markets or gateways. The freight system should follow the economic geography of transformation rather than force every stage toward the port.

Food chains also expose the cost of unreliable energy. Cold rooms, refrigeration, processing and storage can lose their value if electricity is intermittent or expensive. Energy reliability is therefore not a separate utility issue. It is part of freight reliability and food-system productivity.

69. Manufactured consumer goods • the cube, the clock and the market

Manufactured consumer goods often invert the logic of bulk freight. The challenge is less about moving maximum mass and more about coordinating components, packaging, finished units, inventory and distribution across dense markets. Trucks can cube out before they weigh out.

Warehouses become part of the transport system. Service frequency can matter more than maximum payload.

This is where African urbanisation and AfCFTA can materially reshape freight. Larger regional markets can support production runs and distribution networks that were previously uneconomic.

But the gains depend on interoperable standards, predictable borders, payments, warehousing, inventory finance and last-mile distribution. A continental market is not created by tariff schedules alone; it must be physically served.

Industrialisation changes freight from a problem of moving weight into a problem of coordinating productive complexity.

70. Worked Productive Density case • cotton, textiles and garments

A World Bank manufacturing-competitiveness report for Lesotho provides an illustrative cotton-textile-apparel value-addition ladder. Figure 20 is titled 'Cotton Value Addition in the Export Value Chain by stages' and presents approximately US\$1.4 per kilogram for lint, US\$3/kg for yarn, US\$5/kg for fabric and US\$8-10/kg for garments as indicative value added by production stage. These are not universal prices and should not be interpreted as a one-to-one physical conversion series. [E]

The benchmark demonstrates the economic-density argument even before a route model is added: the indicative figure rises from lint to yarn, fabric and garments as transformation deepens. For orientation, the reported stage values are about 2.1 times, 3.6 times and 5.7-7.1 times the lint benchmark respectively. These ratios compare the source's stage values; they do not mean one kilogram of lint becomes one kilogram of each downstream product. Transformation yields, waste, accessories, imported inputs and product mix must be measured separately. The illustration therefore shows the relationship between transformation and economic value, not a physical massbalance identity.

Table 6. Cotton value ladder

Stage	Indicative value / kg	Multiple vs lint	Freight / operating implication
Lint export	US\$1.4	1.0×	Commodity flow; mass-oriented; quality and contamination control matter.
Yarn	US\$3.0	2.1×	Industrial intermediate; electricity, water, technical skills and reliable input logistics deepen.
Fabric	US\$5.0	3.6×	Higher value density; finishing, storage, quality control and production reliability matter more.
Garments	US\$8-10	5.7-7.1×	Labour-intensive, time-sensitive and packaged/cube-sensitive; inventory and expedited freight can matter.

These source-reported historical stage values illustrate transformation; they are not current price quotations or a physical mass-balance identity. Material yields, product specification, conversion cost and ownership determine retained value. [SR]

Productive Yield is not identical to the value multiple. The test remains: how much of the additional processing, supplier activity, skills, ownership, margin and reinvestment is created and retained in Africa? [P]

Source note: World Bank, Enhancing Export Manufacturing Competitiveness in Lesotho / New Markets Diagnostic for Lesotho's Textile and Apparel Sector, Figure 20, 'Cotton Value Addition in the Export Value Chain by stages'. The figure reports indicative value added by production stage per kilogram; exact prices, yields and conversion ratios vary by market, specification and factory.

This hierarchy matters. Architecture defines how the physical economy is organised. Corridors, gateway cities and productive territories provide the operating geography. The Productive Freight Decision Model is the method used to test alternatives. The laboratories are applications of that architecture and method, not substitutes for them.

The laboratories are not presented as nine predetermined investment propositions. They are structured stress tests of the doctrine. Each should be assessed by stating the question, examining geography, movement and productive systems, identifying the hypothesis, reviewing evidence and missing evidence, applying a decision test and assessing Productive Yield.

NINE AFRICAN LABORATORIES

Laboratory Method and Case Framing

The laboratories are structured stress tests of the doctrine, not descriptive case studies.

The laboratory method begins with a question and examines geography, movement and productive systems. It states a hypothesis, reviews evidence and missing evidence, applies a decision test and assesses Productive Yield. The laboratories are selected stress tests, not a representative inventory of African corridors. They expose different combinations of geography, cargo, market structure, regulation, energy and institutional capability.

Reader hierarchy. Five laboratories carry the principal analytical load: Lake Victoria tests middle-mile modal reassignment; Mombasa tests the productive gateway; Abidjan-Lagos tests coastal-road complementarity and short-sea shipping; Durban tests rail, port, energy and industrial depth; and Lobito tests whether a mineral corridor can diversify into a broader productive system. Congo-Ubangi, Niger-Benue, Cotonou/Grand Nokoué and Port Louis operate as comparative laboratories, testing the architecture under different navigability, cargo-generation, metropolitan-orchestration and island-gateway conditions. All nine remain part of the evidence and research programme.

71. Lake Victoria • can the lake become a middle-mile freight system?

Question and geography

Lake Victoria sits inside one of Africa's most commercially active regional geographies. The strategic opportunity is not simply that water exists between Uganda, Tanzania and Kenya. It is that a lake service can potentially replace a long road middle-mile while retaining trucks for collection and delivery.

System and productive mechanism

PIDG reports that the purpose-built MV Mpungu carries 21 fully laden trucks and up to 1,000 tonnes between Port Bell and Mwanza South, reducing the reported journey from three to four days by road to about 18 hours on the lake leg. This is significant because it demonstrates functional reassignment rather than modal ideology. The truck remains part of the service; the long middle section changes mode. [SR] [N5]

The evidence still required for a definitive commercial conclusion is more demanding: door-to-door tariffs, terminal time, sailing frequency, utilisation by direction, cargo mix, seasonal reliability, insurance, driver arrangements, fuel consumption, maintenance economics and the cost of missed sailings. A vessel can be technically successful while the wider system remains commercially thin.

The deeper opportunity is network formation. Kenya Ports Authority reports that Kisumu Port handled 496,516 tonnes in 2025, providing a current signal that lake-port demand is no longer merely theoretical. If Port Bell, Mwanza and Kisumu can connect effectively with railheads, logistics platforms, production territories and metropolitan markets, Lake Victoria can become a switching space within East African freight rather than a barrier around which road freight must travel. [SR]

Evidence and its limits

A lake crossing is one leg of the route. PIDG service descriptions do not independently validate matched door-to-door prices or reliability. Kisumu's 496,516 tonnes is a 2025 source-reported total; the inconsistent growth percentage has been removed.

Decision test and missing evidence

Obtain matched quotations, access and terminal costs, waits, cancellation records, direction-specific loads, fuel and safety evidence. Compare complete routes and apply A21 before infrastructure expansion.

72. Mombasa and the Northern Corridor • can efficiency become productive transformation?

Question and geography

The Northern Corridor is a powerful test of the difference between operational improvement and economic transformation. Port performance, customs, the Single Customs Territory, border coordination, cargo visibility, road quality and rail services can reduce time and cost. Those gains matter in their own right. But the Productive Yield question asks what the improved movement enables beyond movement itself.

System and productive mechanism

The Mombasa work developed the idea of an Authored Transition: lower-carbon movement, lower logistics cost and resilience can reinforce one another through modal shift, asset utilisation, route design, energy and data. It also insists on the question 'what movement leaves behind?' That question should be applied at three scales: the port, the gateway economy and the wider corridor.

At port scale, the issue is interface efficiency and maritime competitiveness. At gateway-economy scale, it is whether logistics, blue-economy activities, industrial services and enterprise capability deepen in Mombasa. At corridor scale, it is whether inland nodes, SEZs, productive territories and markets become more connected and more capable rather than merely easier to traverse.

The freight research programme should therefore separate cargo by commodity and direction, compare road and rail roles, quantify dwell and border distributions rather than averages alone, map inland-depot and lake interfaces, and connect those operational results to enterprise, processing and market outcomes.

Urban logistics is integral to the Mombasa test. Port-city truck circulation, staging, delivery windows, last-mile distribution, wholesale and food logistics, public mobility and land-use interfaces determine whether a large maritime gateway strengthens or degrades metropolitan productivity.

Evidence and its limits

Separate port, gateway-economy and corridor outcomes. Aggregate imports and exports are not container empty-return statistics or a matched corridor backhaul measure.

Decision test and missing evidence

Test urban port-city circulation, commodity/direction flows, inland nodes, borders, rail/lake interfaces and enterprise outcomes at all three scales.

73. Congo-Ubangi • when geography is not yet a system

Question and geography

The Congo Basin is one of the continent's most compelling Source-to-Sea geographies, but it is also a warning against romanticising waterways. The World Bank's Central Africa Regional Waterways Project combines waterways, ports, roads, trade facilitation, safety and cross-country coordination, with the stated objective of improving transport and trade efficiency, climate resilience and socioeconomic inclusion along selected CAR-Republic of Congo corridor sections. That architecture itself reinforces the central point: a river corridor is an institutional and commercial system, not merely a navigable channel. [E]

System and productive mechanism

The economic potential is broad. Agricultural production, food systems, mining regions and secondary cities could connect to river ports and onward Atlantic gateways. Yet seasonality, hydrographic information, dredging and navigation services, fleet condition, port equipment, safety, cargo aggregation, border systems and fragile-state risks can undermine the theoretical advantage of water.

The decision problem is therefore to identify cargo basins large and regular enough to sustain service, determine the minimum reliable navigation window, price the transfers into and out of river transport, and establish which public goods must be funded before private operators can reach commercial scale. The World Bank's project documentation is particularly important here because it notes that nascent traffic volumes and fragility currently limit private financing, making public investment necessary for core enabling assets.

Evidence and its limits

Project documents establish programme aims and enabling constraints; they are not proof that every targeted outcome has been achieved.

Decision test and missing evidence

Identify viable cargo basins, navigation windows, transfer costs, public goods, operating institutions and finance under fragility and hydrological shocks.

74. Niger-Benue and Nigeria's river ports • why infrastructure cannot create cargo

Question and geography

Nigeria's inland-waterway geography invites large ambitions. Baro and Onitsha should be investigated as nodes in a complete freight system: the presence of port infrastructure alone does not establish demand or operating viability. Cargo owners require predictable navigation, service frequency, competitive tariffs, first/last-mile access, security, insurance and operators with sufficient scale. This is a research question, not an independently verified verdict on either port. [P/R]

System and productive mechanism

The Nigeria laboratory should therefore be deliberately sceptical. Its purpose is to identify the break-even conditions under which inland water transport becomes a commercial freight product rather than an infrastructure aspiration. If those conditions cannot be met for a route or cargo, the correct conclusion may be that road remains superior.

That is an important methodological safeguard for the entire monograph. Modal intelligence is valuable precisely because it can say no.

Evidence and its limits

Baro and Onitsha are research nodes here. Infrastructure presence or age alone does not establish commercial success or failure.

Decision test and missing evidence

Measure navigability, cargo, service, tariff, access, security and operating scale; retain road where the complete-route comparison supports it.

75. Abidjan-Lagos • can the coast carry part of the coastal economy?

Question and geography

The Abidjan-Lagos system is not merely a road corridor and should not be reduced to a road-versus-short-sea comparison. It is simultaneously a freight corridor, a chain of metropolitan markets, a concentration of ports, an industrial geography and a potential short-sea circulation system. Its deeper question is how movement between Abidjan, Tema, Lome, Cotonou and Lagos - and their hinterlands - produces greater productive depth rather than merely greater traffic.

The Abidjan-Lagos geography links some of West Africa's largest metropolitan and port economies.

System and productive mechanism

It is also a place where road freight encounters borders, urban congestion and dense coastal settlement. World Bank reporting on the Abidjan-Lagos Trade and Transport Facilitation Project states that the programme reduced truck/merchandise travel and border-crossing times by 47% between 2010 and 2018. The source-reported result illustrates how much performance can be unlocked through institutional and interface reform before a mode changes. [SR] The disaggregated completion indicators in Annex D provide a more bounded test; their reporting periods and endpoints must not be conflated with this programme-level summary. [N24]

The short-sea question begins after that optimisation. Which cargo flows between Abidjan, Tema, Lomé, Cotonou and Lagos are regular and large enough to support predictable coastal services?

Which are too time-sensitive, dispersed or low-volume? How do port charges, handling, first/last mile, sailing frequency and inventory time compare with road border friction and congestion?

A successful short-sea system would not make the coastal highway irrelevant. It would give the coastal economy another trunk option and improve resilience. But the vessel should win only where the complete route wins.

The Abidjan-Lagos laboratory tests a wider Atlantic Productive Doctrine, not only a road-versus-coastal-shipping proposition. The coastal megaregion is simultaneously a freight corridor, a chain of metropolitan markets, a concentration of ports, an industrial geography and a potential short-sea system. Its strategic question is how movement among Abidjan, Tema, Lomé, Cotonou, Lagos and their productive hinterlands can generate greater productive depth rather than merely greater traffic. The doctrine combines coastal-road complementarity, metropolitan density, cabotage and Short-Sea Shipping, carbon sovereignty, Carbon Passports, Industrial Gravity, border economics, supplier ecosystems, value retention and Capture by Measurement. [P]

Evidence and its limits

The 47% project-reported reduction relates to 2010-2018 and a specified programme. It does not establish current short-sea costs or productive additionality.

Decision test and missing evidence

Test coastal-road complementarity, cabotage, sailing economics, metropolitan suppliers, ports, borders, Carbon Passports and value retention.

76. Cotonou and Grand Nokoué • can logistics platforms orchestrate the city and hinterland?

Question and geography

Cotonou introduces the logistics-platform problem. A platform can be a warehouse district, or it can become an orchestrator of flows. Consolidation, cross-docking, truck scheduling, customs integration, urban distribution, industrial adjacency and potential interfaces with rail, inland water or coastal shipping determine which of those roles it performs.

System and productive mechanism

The design experience around Africa Logistics Zone within the Port of Cotonou and the logistics platforms of Grand Nokoué is relevant because it exposes the architecture before implementation: how should port, metropolitan distribution and hinterland flows be separated and recombined?

How can a platform reduce unnecessary truck movement inside the city? Where should customs and data sit? What future modal interfaces should be protected in the land plan?

The laboratory should remain disciplined about evidence. Design knowledge can illuminate the system without being presented as proof that later operational outcomes occurred.

The city-hinterland question should include urban consolidation, metropolitan distribution and the relationship between the logistics platforms, city markets and coastal services. A platform that only stores cargo without improving city distribution or modal switching will not fulfil the wider system role proposed here.

Evidence and its limits

The author's design experience is disclosed. Business models and platform plans explain architecture; they are not evidence of achieved operating performance.

Decision test and missing evidence

Test consolidation, cross-docking, city distribution, customs/data, interfaces, protected land and supplier outcomes against measured baselines.

77. Durban and Southern Africa • can the energy transition strengthen an industrial corridor?

Question and geography

Durban and the North-South system bring together the hardest questions in the monograph: a major port, a large industrial economy, heavy road freight, rail-recovery requirements, energy insecurity, inland gateways and future maritime fuels. It is the principal Fossil-Smart transition laboratory,

testing how efficient residual fossil use, energy diversification and modal rebalancing can strengthen an industrial corridor.

System and productive mechanism

The first task is to identify fossil waste: truck idling and queues, empty returns, inefficient backup generation, avoidable terminal dwell and poorly utilised equipment. The second is modal rebalancing: which long-haul container and bulk flows should move by rail, and what reliability and terminal performance are required for shippers to switch? The third is energy diversification across port equipment, buildings, industrial processes, trucks, rail and maritime services.

Durban also makes Grey Carbon a necessary part of the assessment. New terminals, roads, railways and industrial zones consume cement, steel and construction energy. A transition that optimises operational emissions while repeatedly rebuilding badly located infrastructure can lose part of its climate and economic advantage.

The objective is a corridor that progressively eliminates fossil waste, improves efficiency, restores modal balance, diversifies energy where viable and builds infrastructure with enough optionality to absorb future technology.

The Durban laboratory tests the wider Southern African proposition developed through Durban OceanGate. The port and Durban-Gauteng freight spine are examined not only as a port-and-rail problem but as the potential backbone of a Blue Industrial Economy connected through a productive SEZ chain, a Southern Blue Corridor and a Living Corridor. The test is whether modal rebalancing, energy transition, industrial depth and human geography can reinforce one another rather than remain separate programmes. [P]

Evidence and its limits

Durban OceanGate, the Blue Industrial Economy, Southern Blue Corridor and Living Corridor are authored propositions to test, not certified outcomes.

Decision test and missing evidence

Evaluate rail restoration, queues, empty returns, energy reliability, embodied carbon, SEZ linkages and productive capability under realistic delivery constraints.

Annex F operationalises this laboratory through five zones, eight proposed programmes, progression gates, dashboard units, baseline collection, accountable governance and matched financing. [P]

78. Port Louis and the Indian Ocean • can a port become an energy and coordination node?

Question and geography

Port Louis is a useful counterpoint because its geography is maritime from the beginning.

System and productive mechanism

UNCTAD's Sustainable Smart Port work in Mauritius has assessed the port's readiness to integrate renewable energy and improve energy efficiency, and its 2025 stakeholder process was designed to translate that assessment into a roadmap for energy transition and long-term sustainable port development. That makes the port a live laboratory for the proposition that ports can coordinate energy as well as cargo. [E] [N26]

The Indian Ocean question is larger than Port Louis itself. Short-sea and feeder services can create an extended ocean hinterland in which ports play differentiated roles: aggregation, relay, servicing,

completion and coordination. The economics depend on cargo, frequency, vessel size, transshipment patterns and regional demand, but the architecture is distributed rather than linear.

For Port Louis, solar generation, equipment electrification, shore-power readiness, maritime services and future-fuel optionality should be analysed alongside feeder economics. The energy node and the freight node must reinforce each other; neither should be treated as an isolated sustainability project.

Evidence and its limits

UNCTAD assessment and stakeholder-roadmap activity establish a planning process, not proof of implemented energy or freight performance.

Decision test and missing evidence

Assess actual loads, electricity/fuel, shore-power readiness, feeder demand, tariffs, frequency, utilisation and institutional responsibility.

79. Lobito • can a mineral corridor become a diversified productive corridor?

Question and geography

The Lobito Corridor spans Angola, the Democratic Republic of the Congo and Zambia from the Port of Lobito toward the Copperbelt. The African Development Bank's June 2026 appraisal describes the corridor as historically important to mining while also identifying potential for agricultural and industrial trade. It notes that the Angola-DRC line has been revitalised through the Lobito Atlantic Railway concession and that the rail system presents a business case for interconnection to Zambia.

System and productive mechanism

[E]

The strategic test is whether the corridor remains principally an evacuation route for mineral value or becomes a diversified productive corridor. That requires analysis of at least four layers. First, the concession and rail-access architecture: who controls paths, tariffs, terminals, maintenance obligations and third-party access. Second, the cargo base: present and prospective mineral flows, two-way freight, utilisation and the economics of the Zambia connection. Third, productive geography: where beneficiation, supplier services, agriculture, industrial activity and logistics clusters could become commercially viable. Fourth, interfaces: border processes, port performance, energy, roads and the institutional coordination required across three states. [P]

Evidence still required: commodity-level rail tariffs; concession and third-party access terms; current and projected volumes by direction; train frequency, capacity and utilisation; port charges and dwell; border time; Zambia interconnection costs and timetable; mining origin-destination flows; energy and water requirements for downstream processing; local supplier participation; and the geography of credible agricultural and industrial demand. [R]

The corridor is also moving from concept toward financed implementation. In August 2026, the African Development Bank approved a US\$255 million concessional loan and a US\$10 million grant for Zambia's participation. The Bank describes the approval as the first tranche under ADF-16, with further resource mobilisation envisaged up to US\$500 million; the programme includes approximately 550 km of new railway in Zambia and a 105 km upgrade of the Mwinilunga-Jimbe road. This does not prove the productive-corridor outcome; it strengthens the case for measuring whether new connectivity produces diversified trade, enterprise capability and retained value rather than only greater mineral throughput. [E] [N23] [SR; N4; N23; N30]

Every material freight proposition must be capable of being read simultaneously through three views: commercial performance; physical and environmental performance; and productive-development performance. A development proposition cannot rescue a commercially impossible operating model. Equally, the lowest-cost option does not automatically prevail where it creates weak productive depth, excessive carbon exposure or fragile dependence. The decision discipline therefore requires explicit trade-offs rather than one opaque composite score.

Evidence and its limits

June and August 2026 appraisal/financing statements describe commitments and programme design. New railway, diversified agriculture and retained value are not thereby achieved outcomes.

Decision test and missing evidence

Reconcile concessions/access, tariffs, commodity and directional volumes, trains, borders, port costs, Zambia connection, processing energy/water and credible industrial/agricultural demand.

Doctrine states what the system is trying to achieve. Architecture defines how the economic system is organised. Methodology determines how alternatives are evaluated. Laboratories show where propositions are tested. Metrics determine how performance is measured. The Evidence Sufficiency Gate determines whether the available evidence permits a conclusion. Implementation moves an accepted configuration from diagnosis to execution and ex-post measurement.

Water as a cross-laboratory test

Africa's water geography presents several fundamentally different analytical conditions. They should not be collapsed into a single claim about the potential of inland waterways.

The Great Lakes test whether lake transport can function as an interchange between established terrestrial corridor systems.

The Congo Basin tests the economics and governance of a large multi-country river network in which waterways can constitute primary transport infrastructure rather than an auxiliary mode.

The Senegal River tests river-to-sea architecture and the relationship among inland navigation, river ports, productive territories and coastal gateways.

The Volta system tests a multimodal chain in which maritime gateway, rail, lake transport, road distribution and Sahelian markets can potentially operate as one system.

The Nigerian water system tests a different proposition again: whether rivers, delta channels, lagoons, intracoastal waterways, metropolitan logistics and maritime gateways can be understood as components of a national waterborne network.

These are not presented here as predetermined investment priorities. They are research laboratories through which the Blue Freight Shift can be tested against different African geographies. [R/P]

The distinction is deliberate. OMVS describes a 905 km Saint-Louis-Ambidédi navigation programme integrating a fluvio-maritime port at Saint-Louis, an inland terminus at Ambidédi and river stops; in 2025 SOGENAV tendered dredging and navigation-marking works for the channel. [SR] Ghana's Ministry of Transport reported in September 2026 that a new Volta Lake port is being developed as part of an integrated multimodal system intended to connect cargo movement with northern Ghana and neighbouring landlocked markets. [SR] These systems are comparators to be tested, not predetermined investment priorities.

FROM DOCTRINE TO DECISION

Quantitative Decision Discipline

The quantitative architecture must keep three views visible simultaneously: commercial performance, physical/environmental performance and productive-development performance. No development proposition rescues a commercially impossible operating model; no low-cost option automatically prevails if it locks the economy into weak productive depth, excessive carbon or fragile dependence.

The comparative decision remains conditional on the commercial, service and evidence gates in Chapter IX. Faster sailing alone cannot establish complete-route superiority or productive additionality. [P]

Where a decision-critical variable remains Unknown, the Evidence Sufficiency Gate in A16 applies. The result may be feasibility, conditional feasibility, further research or no-go; it is not automatically an infrastructure recommendation. [P]

80. Foundational measures carried into the decision model

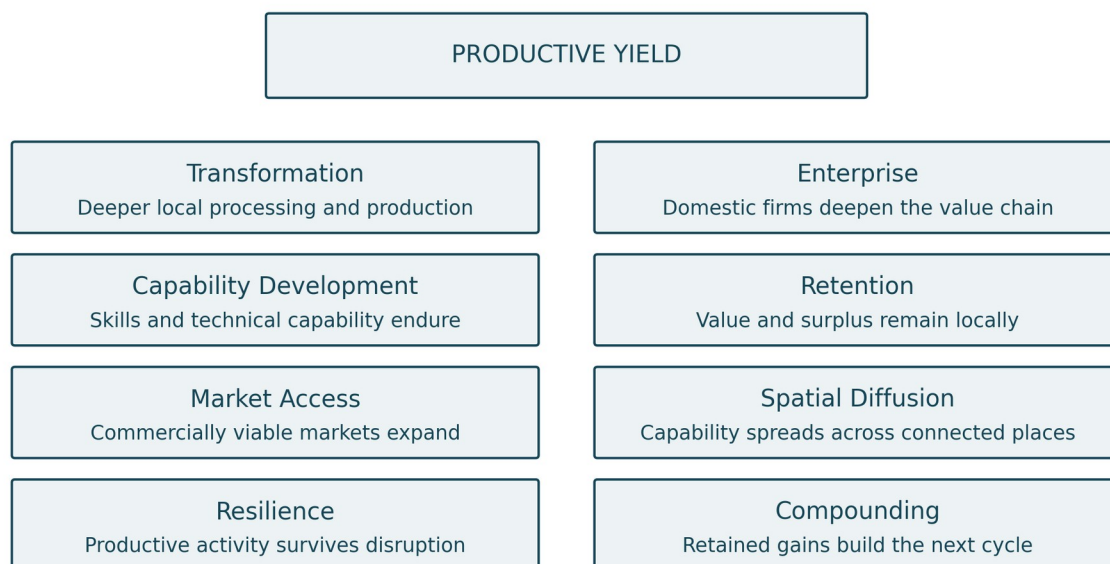
Before the integrated decision process is introduced, three foundational disciplines must remain explicit. First, Total Route Cost compares complete door-to-door routes rather than isolated linehaul prices, including first/last mile, terminal and handling charges, dwell, inventory carrying cost, border/compliance cost, reliability risk, energy and, for public appraisal where relevant, external infrastructure and congestion costs. Second, Productive Yield tests what capability and retained value the movement system creates. Third, carbon and energy measures retain recognised physical accounting boundaries before any developmental ratio is introduced.

These measures are cargo- and service-specific. A tonne of bulk fertiliser, a refrigerated food shipment, a container of garments and a truck carrying construction inputs should not be forced into the same assumptions: cargo value, shelf life, shipment size, service frequency, utilisation and reliability tolerance materially alter the result. Their formal specification and interaction are set out in §§86-98. [P]

81. Productive Yield: canonical definition

Productive Yield is the additional productive capability and retained value that exist because a freight, corridor, urban, energy or infrastructure system is built or improved.

Total Route Cost tells us whether a movement architecture is commercially and operationally credible. Productive Yield asks whether it is developmentally valuable. The two must be used together.



Eight parallel outcome dimensions, each with its own baseline, counterfactual and units.

Figure 10. Productive Yield: Eight Canonical Dimensions

Productive Yield is defined through eight canonical dimensions: Transformation; Enterprise; Capability Development; Retention; Market Access; Spatial Diffusion; Resilience; and Compounding. These eight dimensions are the governing taxonomy everywhere in this monograph. Applications may add context-specific indicators, but they should not silently redefine the dimensions.

This is deliberately more demanding than conventional economic impact. A temporary construction boom can have impact. Productive Yield asks what reproducible capability remains after the spending has passed.

Operationally, Productive Yield should not be forced into one universal monetised number. It is a structured measurement family in which each of the eight canonical dimensions is assessed against a transparent baseline and counterfactual. Where a dimension can be credibly monetised, the monetary value may be reported; where it cannot, its native physical, institutional or capability measure remains visible. Conventional financial, trade, energy and emissions measures remain separate. [P]

82. Productive Economic Zone Additionality Test: a zone-level application

For SEZs and industrial nodes, the six-part Productive Economic Zone Additionality Test is an application of the eight canonical Productive Yield dimensions, not a second definition. Creation captures new Transformation plus Enterprise. Depth tests the quality of Transformation, Enterprise, Capability. Retention maps to Retention. Diffusion maps to Market Access and Spatial Diffusion. Resilience maps directly to Resilience. Compounding maps to Compounding. The zone test therefore asks what new productive activity exists because of the zone, how deep it is, where value remains, whether capability spreads, whether it survives shocks, and whether one cycle creates capacity for the next. [P]

83. Carbon accounting, energy and the measurement hierarchy

Physical carbon accounting remains non-negotiable. ISO 14083:2023 establishes a common methodology for quantifying and reporting greenhouse-gas emissions from passenger and freight

transport-chain operations, and the GLEC Framework v3.2 provides aligned practical multimodal guidance. This monograph therefore treats ISO 14083 / GLEC as the physical emissions-accounting foundation. [E]

Carbon should then be read through four layers: physical emissions, including operational, embodied/Grey and lifecycle carbon; system effects created by idling, congestion, empty running, poor interfaces and unnecessary movement; performance ratios such as carbon per tonne-kilometre, per cubic-metre-kilometre and per unit of productive value; and competitive or market tools used where procurement, finance or market-access requirements make carbon information commercially material. [P]

Energy should be measured per tonne-kilometre or cubic-metre-kilometre where those measures fit the cargo, and also per unit of productive value where the analytical purpose is economic transformation. The Energy Efficiency Index remains a distinct AIC2030 measurement proposition: candidate components include energy per tonne-kilometre, energy per cubic-metre-kilometre, energy per handled unit, energy per unit of productive value, idle-energy share, empty-running energy and facility energy intensity. [P] [E; N2]

84. Carbon competitiveness, Productive Carbon Yield and Carbon Passports

The Carbon Competitiveness Dashboard can adapt a family of measures rather than impose one universal score: Grey Carbon Intensity, Clean Fossil Adoption, Renewable Penetration, Fossil Waste, Energy Efficiency, carbon per tonne-kilometre, Productive Carbon Yield and Green Port or SEZ compliance. Its value is to reveal trade-offs and direct investment, not to create another reporting bureaucracy. [P]

Productive Carbon Yield - productive value created and retained per unit of lifecycle CO₂e - is a complementary development metric, not a substitute for recognised emissions accounting. It asks whether progressively lower-carbon movement is also building productive capability. [P]

As carbon information becomes more relevant to procurement, finance, border measures and buyer requirements, African freight systems may increasingly need product- and chain-level carbon records. The Carbon Passport is the AIC2030 proposition for a traceable data layer linking production, energy, handling and movement to a shipment or product chain. It should use recognised accounting methods, interoperable data and credible verification; it is not presented as an existing universal standard. [P]

Where a dashboard is used, candidate components retain their distinct meaning: Fossil Waste Index, Clean Fossil Adoption Score, Renewable Penetration Index, Energy Efficiency Index, Grey Carbon Intensity, Green Port / SEZ Compliance Score and Productive Carbon Yield. Each requires corridor- or asset-specific calibration and should not be presented as a universal score with predetermined thresholds. [P]

85. Lake Victoria: evidence boundary before model application

Lake Victoria is used as the first empirical laboratory because it can test road-versus-water middle-mile reassignment without assuming that water must win. The purpose of this section is only to establish the evidence boundary before the full decision architecture is applied in §92.

Current source-reported evidence establishes that M.V. Mpungu operates a scheduled RoRo service between Port Bell and Mwanza South; PIDG/EAMT report capacity of up to 21 fully laden trucks or 1,000 tonnes and an approximately 18-hour crossing, compared with a source-reported three-to-four-

day road journey. EAMT publishes a schedule but requires customers to request a formal quotation rather than publishing a standard tariff. [SR] [N5]

A 2015 World Bank/EAC corridor study used an inland-water freight charge of US\$0.0808 per tonnekm for Mwanza-Port Bell and a lake-port nodal cost of US\$11.58 per tonne. These are historical modelling benchmarks, not current M.V. Mpungu tariffs. [SR/R] [N6]

Because current operator and comparable road quotations are not publicly available, the commercial test is expressed as a break-even threshold rather than a fabricated current cost. If R is the current all-road door-to-door price and A is every non-ferry cost in the road-lake-road option, the maximum ferry price consistent with cost parity is $F^* = R - A$. The full decision application in §92 adds Productive Density, Productive Yield, energy, carbon and resilience to this commercial threshold. [P]

Table 7. Lake Victoria scenario inputs

Lake Victoria input	Status	Value / treatment
M.V. Mpungu capacity	[SR]	Up to 21 fully laden trucks / 1,000 tonnes per crossing (PIDG/EAMT).
Crossing time	[SR]	Port Bell-Mwanza: reported 18 hours.
Road time	[SR]	Reported 3-4 days; align origin, destination and timing boundaries before comparison.
Current ferry tariff	[R]	Operator quotation required; not publicly established here.
Current road tariff	[R]	Route- and cargo-specific quotations required.
Historical water charge	[SR]	2015 World Bank/EAC modelling: US\$0.0808/t-km; not a current tariff. Located in the author-uploaded 2015 report, Table 21; not a current tariff. [N6]
Handling / node cost	[R]	Current RoRo costs required; historical US\$11.58/t is a different nodal model.
Carbon	[R]	Actual fuel and energy, allocation and accounting boundary.
Inventory / reliability	[R]	Observed schedule and transit distributions; scenario values labelled [S].

Publication rule: the lake option should not be described as cheaper, lower-carbon or developmentally superior until current operator tariff, comparable road quotations, transfer and waiting time, schedule adherence, utilisation, backhaul, fuel/energy, route-specific GHG and productive-additionality evidence are inserted. Missing decision-critical inputs remain [R].

Evidence basis: [SR] for current operator/project claims; [E] for the historical World Bank/EAC benchmark; [R] for unresolved current commercial, energy, carbon and productive-additionality inputs. Sources: PIDG/EAMT; World Bank/EAC 2015 corridor study.

The methodological point is deliberate: incomplete data should produce an explicit threshold and evidence request, not a false point estimate. A higher all-road price raises the admissible ferry

threshold; additional dwell, tractor-and-driver time, low sailing frequency or greater expected waiting cost lowers it. [P]

This evidence boundary is then carried into §92, where the same case is evaluated through the full six-engine decision architecture rather than repeated as a separate cost model. [P]

86. The Productive Freight Decision Model

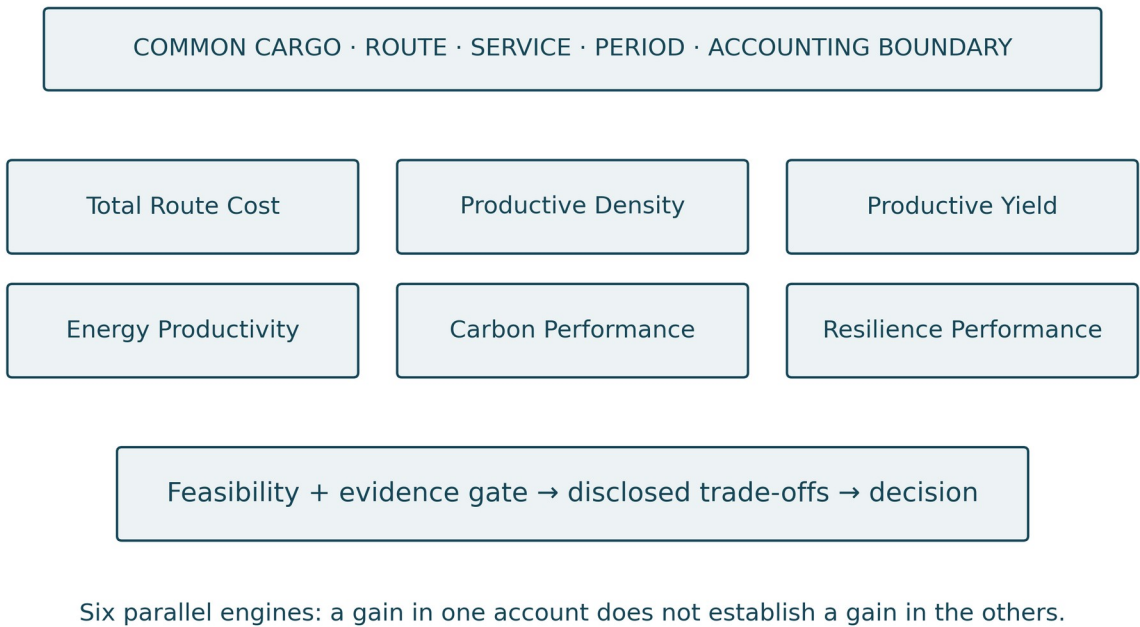


Figure 11. Productive Freight Decision Model

The quantitative architecture brings the monograph’s core measures into one decision process without collapsing them into a single opaque score. It is designed to compare freight-system configurations - routes, modes, nodes, energy systems and associated productive investments against a common baseline. The unit of analysis is a defined cargo or value-chain movement between an origin and destination over a stated period, with a specified service requirement. [P]

The model separates three views that must remain visible at the same time: commercial performance, physical/environmental performance and productive-development performance. A project is not made viable by a high development score if its operating economics fail; nor is a lowcost project automatically preferred if it locks the economy into weak productive depth, excessive carbon or fragile single-path dependence. [P]

Table 8. Six decision engines

Engine	Core question	Primary output
Total Route Cost (TRC)	What does the complete door-to-door movement cost under realistic service conditions?	Currency/shipment, currency/t, currency/unit.
Productive Density (PD)	How much economic and productive value is embodied in what moves?	Currency/t; currency/m ³ ; processing-stage profile.
Productive Yield (PY)	What additional productive capability and retained value exists because the system is built or improved?	Dimension-level additionality; auditable physical/monetary measures for all eight dimensions.
Energy Productivity (EP)	How much useful movement and productive value are obtained per unit of energy?	t-km/MJ; m ³ -km/MJ; attributable productive value/MJ.
Carbon Performance (CP)	What GHG burden accompanies movement and productive value?	Absolute kgCO ₂ e; kgCO ₂ e/t-km; kgCO ₂ e/m ³ -km; scoped productive value/kgCO ₂ e.
Resilience Performance (RP)	How much productive function survives a shock, and how quickly can it recover?	Usable capacity retained; recovery throughput and time; shock cost.

87. The three-layer measurement architecture

Layer 1 - Physical system. Measure tonnes, cubic metres, units, tonne-kilometres, cubic-metrekilometres, vehicle- or vessel-kilometres, capacity, utilisation, dwell, schedule adherence, energy use and GHG emissions. These variables describe what the system physically does. [P]

Layer 2 - Commercial and economic system. Measure Total Route Cost, inventory and workingcapital effects, value density, handling and interface costs, investment requirements, operating cost and where relevant public external costs. These variables establish whether the configuration can operate economically. [P]

Layer 3 - Productive-development system. Measure incremental processing, supplier participation, enterprise capability, skills, domestic ownership and retained margin, market access, productive spatial effects, capital formation and reinvestment. These variables establish what the movement system leaves behind. [P]

The layers are linked but not interchangeable. A tonne-kilometre is a physical quantity; a dollar of retained margin is an economic quantity; recovery time is a resilience quantity. The model therefore preserves native units and uses normalisation only for transparent scenario comparison, not to disguise unlike measures as one physical quantity. [P]

88. Formal specification of the six engines

Total Route Cost uses one accounting perspective at a time. In the shipper tariff model: TRC = quoted complete-route charges + explicitly excluded access, terminal and compliance charges + inventory carrying cost + separately payable asset/driver detention + expected reliability loss + other excluded charges. Record exactly what each quotation includes. Fuel and empty-return costs already embedded in a tariff must not be added again.

In the operator resource-cost model: $TRC = \text{allocated fuel/electricity} + \text{labour} + \text{asset ownership/lease and maintenance} + \text{access, terminal and compliance resources} + \text{empty-return resources} + \text{inventory and reliability costs relevant to the chosen perspective}$. Do not add a full commercial tariff to these same underlying resources. Asset/driver time is distinct from cargo inventory financing; avoid charging one loss in both reliability and inventory accounts.

Public appraisal records infrastructure, congestion and other external costs in a separate social account. Taxes, transfers and financial charges follow the applicable appraisal convention; private and public perspectives are not mixed invisibly. [P]

Productive Density. At minimum: mass value density $MVD = \text{economic value} / \text{tonnes}$; volumetric value density $VVD = \text{economic value} / \text{m}^3$. For developmental analysis, the value-density profile should also record processing stage and domestic value retained, because a high-value imported finished product can have high commercial density but low domestic productive depth. [P]

Productive Yield. For each canonical dimension j and scenario s , measure additionality against the defined counterfactual: $\Delta PY_{j,s} = \text{Outcome}_{j,s} - \text{Outcome}_{j,\text{counterfactual}}$. The eight dimensions are: Transformation; Enterprise; Capability Development; Retention; Market Access; Spatial Diffusion; Resilience; and Compounding. Where a dimension can be credibly monetised, report the monetary value; where it cannot, retain the native physical or institutional measure and an explicit evidence state. Do not force all dimensions into money. [P]

Energy Productivity. Physical energy productivity can be expressed as $EP_{\text{transport}} = \text{transport work} / \text{energy consumed}$, for example tonne-km/MJ or $\text{m}^3\text{-km/MJ}$. Developmental energy productivity can be expressed as $EP_{\text{productive}} = \text{incremental productive value retained} / \text{energy consumed}$. The latter is meaningful only where productive value has been measured consistently and must not replace engineering energy-efficiency metrics. [P]

Carbon Performance. Use recognised transport-chain accounting first. $CI_{\text{transport}} = \text{lifecycle or operational CO}_2\text{e} / \text{transport work}$, with the boundary stated. Productive Carbon Yield is $PCY = \text{incremental productive value created and retained} / \text{lifecycle CO}_2\text{e}$. PCY is a complementary developmental ratio; it does not offset or erase absolute emissions. [P]

For a monetary Productive Carbon Yield, use attributable incremental retained gross value added divided by matched lifecycle CO_2e . Declare currency, price year, horizon, geography and the treatment of resident workers, domestic owners and the public account. Wages, profits and taxes must not be added again to a GVA total that already contains them. Gross output is not GVA. The ratio does not monetise all eight dimensions. A zero denominator is undefined; negative additionality is reported explicitly, and absolute emissions remain visible. [P]

Resilience Performance measures usable alternative capacity, substitution, recovery and shock loss. Modal Redundancy Factor = $\text{usable alternative capacity} / \text{normal throughput}$, using the same period, cargo and service specification. Confirm rights, technical compatibility, activation time and commercial availability; exclude inaccessible or double-booked capacity. A capacity ratio above one does not mean more than all normal throughput can be substituted.

Recovery Throughput Factor = $\text{productive throughput restored during a defined recovery window} / \text{normal productive throughput during the same-length reference window}$. State the window and baseline. Elapsed time to minimum service and to full recovery remain separate measures. Report expected shock loss only where probabilities are defensible; otherwise use explicit deterministic stress tests. [P]

89. Productive Yield measurement matrix

Productive Yield becomes testable only when each dimension is tied to an observable baseline and a defined counterfactual. The following measurement family is the minimum specification; corridor and value-chain applications may add measures but should not silently change their meaning. [P]

Table 9. Eight Productive Yield dimensions

Dimension	Candidate observable measures	Decision meaning
Transformation	Share processed locally; processing-stage shift; new productive capacity; output of first/secondary transformation.	Does movement enable deeper production rather than evacuation alone?
Enterprise	Local procurement share; number/value of qualified supplier contracts; firm graduation; logistics/industrial service depth.	Are domestic firms entering and deepening the value chain?
Capability Development	Skilled jobs; certified technicians/operators; training completion; local engineering/maintenance capability.	Is reproducible capability being built?
Retention	Domestic value added; retained margin; local ownership/income; tax base; domestic reinvestment.	Where does the economic surplus remain?
Market Access	New reachable markets; delivered-cost reduction; service-frequency improvement; export diversification.	Does the system enlarge commercially viable demand?
Spatial Diffusion	Productive nodes connected; secondary-city participation; supplier activity beyond enclave/fence.	Does capability spread across the connected geography?
Resilience	Output protected during shocks; supplier substitution; recovery time; inventory shortfall avoided.	Can productive activity survive disruption?
Compounding	Reinvestment rate; repeat investment; new firms/capacity generated from retained income and knowledge.	Does one cycle create the capacity for the next?

Assess each measure against a dated baseline and credible counterfactual. Native units remain visible; a dashboard is not evidence of causation. [P]

90. From metrics to an investment decision

Normalise ratios only against positive, meaningful baselines. Zero, negative or near-zero baselines require differences, ranges or native-unit presentation. Disclose directions, scaling, weights and missing values; do not treat an unknown as zero. [P]

The model uses a staged decision rule rather than a predetermined weighted score. Stage 1 - Feasibility gate: eliminate or redesign scenarios that cannot meet essential service, safety, legal, capacity or minimum commercial conditions. Stage 2 - Dominance test: identify scenarios that are no worse on all material dimensions and better on at least one. Stage 3 - Trade-off frontier: where no scenario dominates, expose the cost of improving one objective in terms of another. Stage 4 - Threshold test: apply explicit policy or investor constraints such as maximum TRC, minimum

reliability, carbon budget, debt-service requirement or minimum productive additionality. Stage 5 - Sensitivity and stress test: vary uncertain inputs and test shocks before a decision is taken. [P]

Institutional execution capability is an explicit Stage 1 feasibility gate in every geographical laboratory. The assessment must identify the accountable authorities and operators, effective operating and access rights, required permits or cabotage permissions, cross-border clearance arrangements, and the staff, budget and enforcement capacity needed to deliver the proposed service. Coordination responsibilities, dispute resolution and an operational activation test should be documented. Formal agreements alone do not demonstrate executable capability. If a decision-critical requirement is absent or Unknown, the configuration cannot receive an unconditional investment recommendation: it should be deferred, redesigned or advanced through a bounded demonstration with explicit conditions for resolving the gap. [P]

A composite score may be used only as a secondary presentation tool after the native measures are shown. Any weights must be declared, justified by the decision-maker and subjected to sensitivity analysis. The monograph does not prescribe universal weights for cost, carbon, Productive Yield, energy or resilience. [P]

For scenario comparison, dimensionless change can be reported transparently against the baseline.

For a measure where higher is better: $I_{x,s} = X_s / X_{\text{baseline}}$. Where lower is better, such as cost or carbon intensity: $I_{x,s} = X_{\text{baseline}} / X_s$. These indices aid comparison but do not convert the underlying measures into the same economic substance. [P]

91. Uncertainty, sensitivity and evidence discipline

Every quantitative result should identify both the claim status of the statement and the maturity state of each material input. Claim markers remain [E], [SR], [P], [S] and [R]. Model inputs use the separate maturity states Measured, Reconciled, Estimated, Scenario and Unknown. A model result is not stronger than the material inputs and assumptions on which it depends. [P]

Minimum sensitivity analysis should vary demand, utilisation, tariff/fuel/energy price, handling and dwell, service frequency, inventory value, reliability, backhaul/empty running and capital cost where these variables can change the preferred configuration. Scenario ranges should be published rather than hidden behind a single point estimate. [P]

For high-capital or high-uncertainty decisions, probabilistic analysis may be added where defensible distributions exist. Monte Carlo simulation is useful only when the distributions themselves are evidence-based; it should not be used to give false precision to unsupported assumptions. Deterministic stress tests remain preferable where evidence is thin. [P]

92. Worked decision architecture: Lake Victoria

The Lake Victoria laboratory can now be read as a complete decision template rather than a freight-price comparison. Define a baseline all-road scenario and at least one multimodal scenario such as road-lake-road. Where rail interfaces are commercially available, a rail-lake-road scenario can be added. The model should use the same cargo, origin, destination, shipment size and service requirement across scenarios. [P]

Table 10. Lake Victoria decision template

Engine	Road baseline	Road-lake-road	Missing evidence
Total Route Cost	Current door-to-door road quotation plus time/reliability costs.	Ferry quote plus access/drayage, handling, waiting, time and reliability.	Current commercial quotations, transfer arrangements, waiting and schedule adherence.
Productive Density	Same cargo baseline; record value/t and value/m ³ .	Same cargo unless the modal change enables different processing/packaging.	Cargo/value-chain data and processing-stage assumptions.
Productive Yield	Baseline local processing, suppliers, skills, retained margin and market reach.	Incremental outcomes attributable to the multimodal configuration.	Counterfactual enterprise/value-chain evidence; avoid attributing unrelated development.
Energy Productivity	Road fuel/energy per transport work.	Road access, vessel and terminal energy per transport work.	Route-specific fuel/energy, utilisation and allocation.
Carbon Performance	Route GHG using recognised accounting boundary.	Road, terminal and vessel GHG on the same boundary.	Current energy/fuel data and emission factors; lifecycle scope stated.
Resilience Performance	Road disruption exposure and alternative capacity.	Lake service adds or changes redundancy but introduces sailing-frequency dependence.	Executable alternative capacity, shock scenarios, recovery time and service continuity.

Decision output. The multimodal option becomes an investment candidate only when commercial and service gates pass and productive, energy, carbon and resilience performance is superior or represents an explicit acceptable trade-off. Until decision-critical research inputs are filled, report thresholds and break-even conditions rather than a recommendation. [P]

93. Investment appraisal and capital allocation

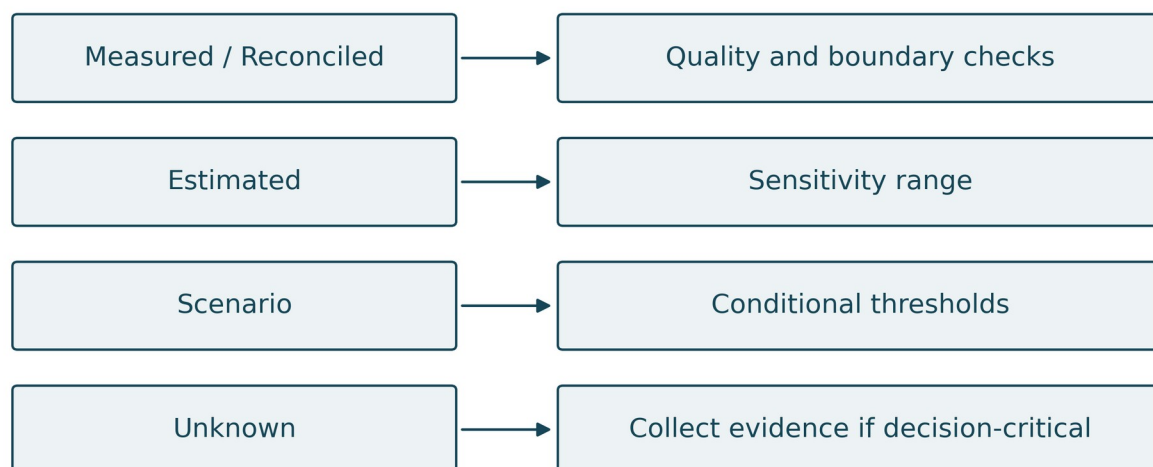
The Productive Freight Decision Model does not replace conventional financial and economic appraisal. It sits alongside them. Financial appraisal asks whether project cash flows can support the capital structure. Economic appraisal asks whether wider social benefits and costs justify intervention. The Productive Freight Decision Model adds a freight-system test: whether the proposed configuration changes the productive structure, movement economics, energy use, carbon burden and resilience in the direction claimed. [P]

For capital allocation, the model should therefore be read with NPV, IRR, DSCR or equivalent financial measures where relevant, and with economic cost-benefit analysis for public investment.

Productive Yield should not be double-counted as a separate benefit when the same value has already been monetised inside an economic appraisal. The audit trail must state where each benefit enters. [P]

The practical investment question becomes: for each dollar of capital committed, what change occurs in complete route cost, productive capability and retained value, energy requirement, lifecycle carbon and shock resilience - and which of those changes are genuinely additional to the counterfactual? [P]

94. Evidence Sufficiency Gate: when the model is allowed to conclude



Evidence states are categories, not automatic stages of maturation.

Figure 12. Evidence Sufficiency Gate

A decision model should be capable of refusing to produce a conclusion. Before a scenario can be described as preferred, every material input should pass an Evidence Sufficiency Gate. The purpose is not to demand perfect data; it is to prevent source-reported claims, assumptions and unknowns from being silently converted into decision-grade facts. [P]

Five input-maturity states are used inside the model: Measured - directly observed for the defined route, asset or period; Reconciled - traceable evidence cross-checked or reconciled across credible sources; Estimated - derived from a stated method and evidence base; Scenario - deliberately assumed to test a future condition; Unknown - material evidence not yet available. These states complement, rather than replace, the claim markers [E], [SR], [P], [S] and [R]. The crosswalk in How to Read the Evidence prevents an input maturity label from being mistaken for a claim about the entire work. [P]

Decision rule. A scenario may be modelled with Estimated and Scenario inputs, but the output must inherit the uncertainty of its material inputs. If an Unknown variable can reverse the preferred configuration, the model should return a threshold, break-even condition or research requirement rather than a recommendation. [P]

Table 11. Input maturity and permitted model use

Input maturity	Meaning	Permitted use
Measured	Direct observation for route, asset and period.	Decision-grade subject to quality checks.
Reconciled	Traceable evidence cross-checked.	Decision-grade subject to consistent boundaries and source quality.
Estimated	Stated method and evidence base.	Sensitivity range required.
Scenario	Explicit future or illustrative assumption.	Scenario testing; never observed evidence.
Unknown	Material input unavailable.	No point conclusion if it can change the decision.

95. Causality, counterfactuals and Productive Yield additionality

Productive Yield measures what changes because of the intervention. Attributable Productive Yield = outcome under the intervention minus outcome under a credible counterfactual. The counterfactual includes expected unrelated economic and policy changes. Adjust separately for unrelated effects only where they were not already represented, and document the identification method and its limitations. Subtracting the same unrelated change twice understates additionality. [P]

The counterfactual should be defined before the preferred project is selected. It may be a dominimum case, a continuation of current operations, or a credible alternative investment. Where causal attribution is weak, the framework should report association and contribution rather than claim causation. Complementary policies - power, skills, industrial land, customs, competition, finance and market access - should be modelled explicitly because transport infrastructure alone may be insufficient to generate wider economic benefits. [P] Roberts, Melecky, Bougna and Xu (World Bank, 2018) review the wider economic benefits and costs of transport corridors and the difficulty of attributing outcomes beyond direct transport effects; UK Department for Transport TAG similarly separates direct cost-benefit appraisal from wider economic-impact analysis. [E] [N37]

Attribution should strengthen progressively: theory of change; baseline and counterfactual; before/after measurement; comparison geography or control where feasible; firm- and value-chain evidence; and ex-post validation. Econometric or quasi-experimental methods may be used where data permit, but methodological sophistication should not substitute for a credible identification strategy. [P]

96. Time, discounting and the productive-development horizon

Freight benefits do not arrive on one clock. Operating-cost savings can appear immediately; supplier development, industrial clustering, skills, land-use change and reinvestment may take years. The model therefore separates operational, investment and productive-development horizons rather than compressing all outcomes into a single-year snapshot. [P]

At minimum, scenario appraisal should distinguish Year 0 / construction, Years 1-5 / operational stabilisation, Years 5-10 / productive response, and Years 10-30 / structural and lifecycle effects where the asset life warrants it. Financial and monetisable economic flows should be discounted using the applicable appraisal convention. Physical measures such as tonnes, energy and CO₂e

should also be reported undiscounted so that discounting does not conceal the underlying physical trajectory. [P]

Where timing is uncertain, the model should test delayed-ramp-up cases. A project whose economic case depends on rapid industrial response should be stress-tested against slower enterprise entry, lower utilisation and deferred complementary investment. Optionality has value: modular, scalable or stage-gated investments can be compared with irreversible build-out where uncertainty is material. [P]

Table 12. Appraisal horizons

Horizon	Primary question	Measures
0-2 years	Delivery and commissioning?	CAPEX, construction risk, readiness and transition cost.
1-5 years	Operating stabilisation?	TRC, utilisation, reliability, energy, carbon and cash flow.
5-10 years	Productive response?	Processing, suppliers, skills, market reach and retained value.
10-30 years	Does capability compound and remain resilient?	Reinvestment, spatial effects, lifecycle carbon, renewal and shock performance.

97. Distribution, place and who captures the gain

Average benefits can hide absolute or relative losers. A freight investment may lower national logistics cost while concentrating land-value gains, displacing informal activity, weakening one gateway, or transferring rents between carriers, shippers, workers, consumers and government.

The model therefore adds a distributional lens alongside aggregate Productive Yield. [P]

For each material scenario, benefits and costs should be mapped at least across: cargo owners and shippers; carriers and logistics providers; workers; consumers; domestic suppliers and enterprises; cities and secondary territories; public authorities; and affected communities. Where gender, income, firm size or geographic access materially changes the outcome, those differences should be reported rather than averaged away. [P]

This does not require every distributional effect to be monetised. It requires the decision record to show who gains, who pays, who bears transition risk and which complementary measures are needed to prevent productive transformation from becoming enclave growth. [P]

98. Reproducibility, ex-post evaluation and the learning freight system

A methodology becomes institutional only when another analyst can reproduce the result. Every application should therefore preserve a model register containing data source, date, unit, boundary, transformation, assumption, evidence status, owner and version for each material variable. Scenario definitions and formulas should be version-controlled, and results should be reproducible from the archived input set. [P]

Ex-ante appraisal should be paired with ex-post evaluation. The baseline must be frozen before implementation; operational indicators should be observed after commissioning; Productive Yield

outcomes should be revisited at defined intervals; and forecast-versus-actual error should be published. This turns the framework into a learning system rather than a one-off justification exercise. [P] The International Transport Forum/OECD, in *Broadening Transport Appraisal* (2022), calls for appraisal to account explicitly for uncertainty, wider objectives and systematic ex-post evaluation; UK Department for Transport TAG maintains dedicated guidance for appraisal, modelling and evaluation. [E]

The strongest test of the framework is therefore not whether it produces a persuasive number. It is whether it can be wrong transparently, reveal why it was wrong, and improve the next decision. [P]

A worked numerical illustration: when the lake option wins and loses

All numbers in this illustration are explicit Scenario inputs [S]. They are not quotations or a validation of M.V. Mpungu. The purpose is to expose the model's arithmetic, constraints and reversals. Annex B supplies a reproducible ledger.

Compare a 20-tonne, 50 m³ shipment valued at US\$40,000. Annual inventory financing is 20%, giving US\$21.9178 per day. The maximum acceptable complete-route transit is four days. The same cargo and origin/destination are held constant.

Table 13. Route cost comparison

Cost account, US\$/shipment	Road	Road-lake-road
Quoted road / ferry charge	1,600.00	900.00
Excluded compliance	100.00	80.00
Access and terminals	Included in road quote	300.00 + 160.00
Separately charged truck / driver time	Included in quote	80/day × 2.5 = 200.00
Inventory cost	3.5 days × 21.9178 = 76.71	2.5 days × 21.9178 = 54.79
Expected reliability loss	120.00	80.00
Total Route Cost	1,896.71	1,774.79

The lake configuration saves US\$121.92 per shipment, or 6.43%, at one day of departure waiting. Its 2.5 days comprise 0.5 access, 0.75 sailing, 0.25 terminals and 1.0 waiting. The road quote includes access, fuel, empty return and asset time; these costs are not added again. Lake truck/driver time is an explicitly excluded charge. Reliability losses are separate from the financing account.

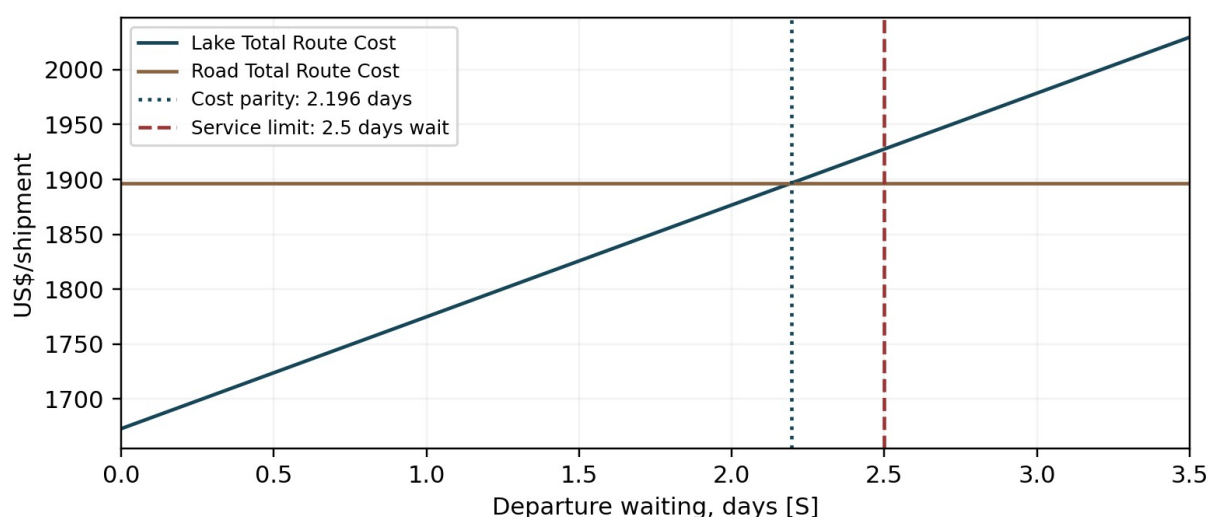


Figure 13. Waiting-Time Cost and Service Thresholds

Table 14. Waiting-time stress tests

Stress [S]	Lake TRC, US\$	Transit, days	Decision
Waiting = 2.0 days	1,876.71	3.5	Saving falls to US\$20.00.
Waiting = 2.5 days	1,927.67	4.0	Service passes; cost loses by US\$30.96.
Waiting = 3.0 days	1,978.63	4.5	Cost and service gates fail.
Ferry charge = US\$1,100; wait = 1	1,974.79	2.5	Cost loses by US\$78.08.
Cancellation adds two days	Recalculate extra time and loss	4.5	Four-day service gate fails.

Cost parity occurs at waiting of approximately 2.20 days. The service limit permits waiting up to 2.5 days, so the commercial condition binds first in this scenario. The maximum ferry charge at one day of waiting is US\$1,021.92. If arrivals are uniform and uncoordinated, expected wait equals half the departure interval; the parity interval is then approximately 4.39 days. That relationship does not apply automatically to booked or coordinated departures.

Table 15. Physical performance comparison

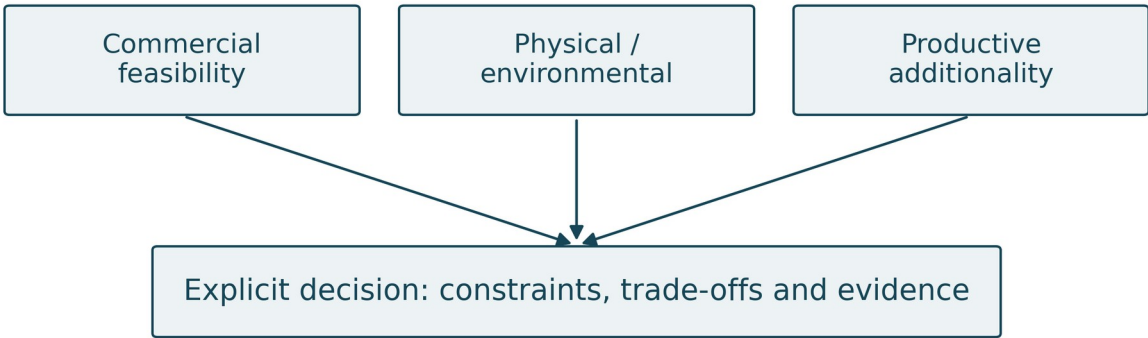
Physical measure [S]	Road	Road-lake-road
Fuel / node electricity	400 litres; 20 kWh	80 litres access + 160 litres allocated vessel; 30 kWh
Energy: 36 MJ/litre; 3.6 MJ/kWh	14,472 MJ	8,748 MJ
Transport work	20 t × 1,000 km = 20,000 t-km	20 t × (200 + 300 km) = 10,000 t-km
Transport energy productivity	1.382 t-km/MJ	1.143 t-km/MJ
GHG: 3.2 kgCO ₂ e/litre; 0.5 kg/kWh	1,290 kgCO ₂ e	783 kgCO ₂ e

Lower total energy does not mean higher tonne-kilometres per MJ: the routes perform different quantities of transport work. Compare shipment energy alongside work intensity and delivered service. These illustrative factors represent a limited fuel/electricity inventory; embodied assets and other unmeasured lifecycle effects remain unresolved. Do not describe the result as complete lifecycle carbon.

Holding access energy and factors fixed, lake GHG = $271 + 512/u$ kgCO₂e, where u is vessel utilisation relative to the reference allocation. Carbon parity occurs at approximately 50.25% utilisation. At u = 0.5 the result is 1,295 kgCO₂e, slightly above road. This isolates allocation sensitivity; lower utilisation could also change the tariff and sailing viability, which require a joint scenario.

No processing change is assumed: Productive Density remains US\$2,000/t and US\$800/m³. A separate supplier-development programme costing US\$25,000/year across 1,000 shipments adds US\$25/shipment and reduces the logistics saving to US\$96.92. An illustrative complementary programme may produce US\$40,000/year attributable retained GVA, four trained technicians and three qualified suppliers [S]; those outcomes require causal evidence and a separately declared boundary. They are not automatically caused by changing mode and are not added to the shipper saving as the same benefit.

For resilience, assume a 14-day road outage and verified alternative capacity able to carry 30% of shipments within 48 hours [S]. Report usable capacity, activation, recovery window, cargo compatibility and cost. The assumed capacity is not evidence that the current lake service can supply that redundancy. A recommendation remains conditional on observed inputs and the Evidence Sufficiency Gate.



Maintain three accounts; do not monetise or add incomparable benefits invisibly.

Figure 14. Three Accounts, One Explicit Decision

IMPLEMENTATION, EVIDENCE AND RESEARCH

The sequence is an evidence discipline: diagnose, model, prioritise, bank, integrate and measure. It is therefore more than a project-development slogan.

DIAGNOSE establishes the actual freight, productive, energy, institutional and political-economy baseline. MODEL tests complete-route configurations and counterfactuals. PRIORITISE identifies interventions that survive the commercial, physical, productive, energy, carbon and resilience tests. BANK translates the preferred configuration into financial and economic appraisal without double-counting Productive Yield. INTEGRATE aligns infrastructure, operations, energy, land use, borders, digital systems and productive investment. MEASURE determines whether the claimed commercial, productive, energy, carbon and resilience outcomes actually occurred.

99. What Africa needs to know about its freight

A recurring problem across the laboratories is not simply missing infrastructure but missing decision-grade data. Commodity origin-destination flows are often incomplete. Door-to-door freight rates are commercially sensitive. Waiting and border times are reported as averages rather than distributions. Empty running is poorly measured. Energy use by route and equipment is rarely integrated with cargo data. Value retention and supplier participation are even less visible.

A serious freight agenda therefore requires observatories that combine physical, commercial and productive data. Their purpose is not surveillance of operators. It is to make investment and policy decisions with a clearer view of where friction, leakage and underused capacity actually sit.

100. Minimum dataset for a productive-freight pilot

Table 16. Minimum dataset for a productive-freight pilot

Family	Minimum fields	Responsible source
Movement	Origin, destination, distance by leg, mode, commodity/cargo, mass, volume, load unit, shipment size and frequency; production territory, industrial node, border, port and market.	Shipper and carrier
Service	Transit-time distribution, dwell, waiting, service frequency, schedule adherence, reliability, utilisation, loss, damage and spoilage.	Carrier, terminals, cargo owner
Cost	Dated line-haul and complete-route quotes with inclusion schedules; access/drayage and first/last mile; terminal/handling, storage, border/compliance, inventory, insurance, reliability, energy, empty return and administration. Avoid duplicate charges.	Shipper, carrier, terminals
Productive Density	Cargo value and value band; domestic value retained; processing stage; mass/volume; perishability and handling constraints.	Producer and customs
Productive Yield	Baseline, scenario/intervention and counterfactual outcomes for all eight canonical dimensions, with attributable physical and monetary measures where defensible.	Firms, labour, fiscal/statistical bodies
Energy	Fuel/electricity by leg and node; energy source; facility energy; utilisation; asset duty cycle.	Carrier and energy supplier
Carbon	Operational and lifecycle boundary; emission factors; GHG by leg/node; material Grey Carbon and embodied assets where relevant.	Emissions accountant and carrier
Resilience	Usable alternative capacity, dependency, shock type, retained service, activation time, recovery time/window and shock loss.	Operators and corridor authority
Capital	Capex, opex, asset life, utilisation ramp and financing terms where applicable.	Sponsor and lender
Evidence	Source, date, geography, claim-status marker, input maturity, confidence/range, units and provenance.	Data custodian and reviewer
Asset	Vehicle/vessel/wagon type, capacity, age, duty cycle and empty-return behaviour.	Carrier, asset owner and technical custodian

Each record carries source, time stamp, geography, units, inclusion boundaries, input-maturity state and uncertainty range. Collect both directions, access legs, terminal activity and failed/cancelled services; use the same origin, destination, cargo and service requirement across alternatives.

THE AFRICAN WATER CORRIDORS EMPIRICAL PROGRAMME

The Blue Freight Shift requires a stronger continental evidence base. Africa does not yet possess a single decision-ready dataset connecting waterway characteristics, inland ports, cargo flows,

productive geography, terrestrial interfaces, commercial services, institutions and coastal connectivity on common definitions. [R]

An AIC2030 empirical programme should progressively build this evidence through four linked inventories:

Water Systems , commercially relevant rivers, lakes, lagoons, reservoirs and navigable sections. Water Gateways , inland ports, river ports, lake ports, metropolitan water terminals and multimodal transfer nodes. Productive Geography , agricultural systems, minerals, manufacturing, fisheries, energy, industrial zones, enterprise clusters, cities and markets connected to those nodes. Short-Sea Networks , coastal gateways, existing and proposed services, cabotage regimes, fleet requirements and potential gateway-to-gateway connections.

The objective is not to produce a continental list of waterways. It is to identify where complete economic systems may exist and what evidence would be required to establish their viability.

Begin with an inventory, verify it and map the productive geography. Test multimodality, commercial demand, governance and investment. Assess Productive Yield before reaching a feasibility or no-go decision.

The final step is deliberately not “build”. Some waterways will prove strategically important. Some may justify rehabilitation. Some may support only local passenger or freight services. Some proposed modal shifts will fail the commercial test. An evidence-disciplined architecture must be capable of distinguishing among them. [P/R]

Productive Yield: indicators for the eight canonical dimensions - Transformation; Enterprise; Capability Development; Retention; Market Access; Spatial Diffusion; Resilience; and Compounding - measured against the defined counterfactual.

101. What should be modelled before it is built

Every major freight intervention should be stress-tested before capital is committed. A waterway service needs utilisation and frequency sensitivity. A rail shift needs service-reliability and terminal assumptions. A charging corridor needs grid capacity, charging dwell and fleet duty cycles. Shore power needs vessel demand and electricity economics. An SEZ needs market, supplier and energy tests. A logistics platform needs actual flow and land-use analysis.

This is the meaning of Future-Ready in practical terms: not predicting one technological future, but protecting enough optionality that the system can evolve without repeated expensive reconstruction.

102. What this means for governments, operators and investors

Table 17. Stakeholder responsibilities

Actor	Primary decision	Evidence before action
Governments / corridor institutions	Set modal, access, border, land-use and public-investment rules around whole-system outcomes.	Baseline demand, Total Route Cost, public-good case, distributional effects and implementation authority.
Ports / infrastructure managers	Improve interfaces, access regimes, staging, rail/water connectivity and data interoperability.	Dwell and reliability distributions, access demand, terminal economics, capacity and service data.
Operators / logistics providers	Choose services, fleets, schedules, consolidation and energy systems that work commercially door to door.	Current tariffs, utilisation, backhaul, labour/asset time, fuel or electricity use and service reliability.
SEZ / industrial investors	Locate production where resource, energy, skills, logistics and markets create defensible productive economics.	Demand, input/output flows, supplier base, utilities, market access and productive additionality.
Energy developers	Build energy around credible freight and industrial offtake rather than technology targets.	Duty cycles, load profiles, offtake contracts, grid conditions, capex/opex and lifecycle emissions.
DFIs / commercial capital	Finance projects whose risk allocation and cash flows are explicit and whose public or productive case is measurable.	Bankability model, sensitivity tests, revenue/offtake, concession rights, governance and environmental/social baseline.

103. Evidence and bankability before capital

The final publication discipline is simple: no improvement claim without a baseline; no major mode or technology proposition without feasibility; no bankability claim without operator economics; no single forecast without sensitivity testing; and no blueprint treated as an achieved outcome. Publicgood projects and commercially bankable projects may both be justified, but they require different financing logic.

The purpose of evidence is not to make the monograph cautious to the point of irrelevance. It is to identify exactly where a proposition becomes an investment decision.

Does-not-claim guardrails are part of the evidence discipline. A proposition should not be presented as an achieved outcome; a source-reported figure should not be upgraded into independently established evidence; a technically possible modal shift should not be called commercially viable without current operator economics; and a lower-carbon option should not be called cheaper, more reliable or more productive until the relevant baseline is measured. [P]

104. The implementation sequence

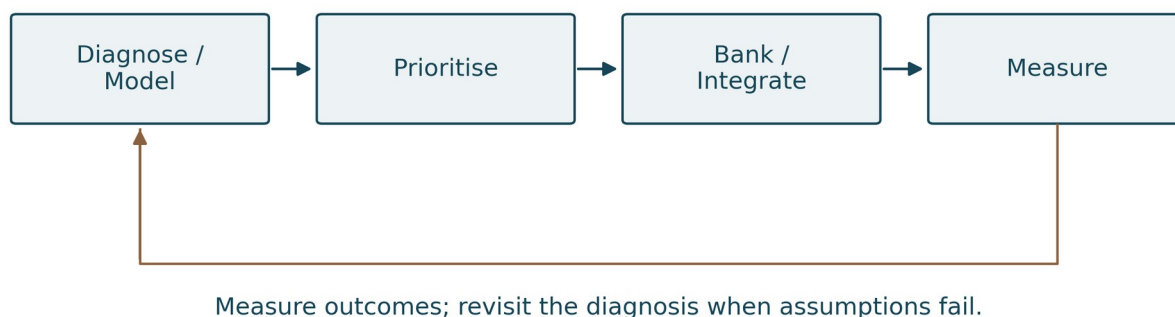


Figure 15. Implementation Sequence

Diagnose and model, prioritise and bank, then integrate and measure.

Measure tracks whether the claimed commercial, productive, energy, carbon and resilience outcomes actually occur.

105. A political-economy diagnostic before implementation

Every implementation programme should identify who benefits from the current friction, who pays for it, who controls the reform lever and who can block change. The diagnostic should map formal authority, commercial incentives, informal rents, access rights, concession obligations, data control, security risks and the distributional consequences of reform. [P]

This is the institutional counterpart to Total Route Cost: the cheapest technical solution may still fail if the political and commercial incentives required to operate it do not exist.

106. Research agenda, validation and continuous improvement

The remaining research agenda is empirical rather than conceptual. Priority work should populate one Productive Density chain, obtain current route quotations and dwell distributions for the Lake Victoria case, refresh Mombasa and Durban modal and terminal data, quantify Abidjan-Lagos road-versus-short-sea economics including cabotage, and add operator economics to Lobito.

The ongoing empirical programme should update the statistical baseline for intra-African trade, corridor mode shares, logistics costs, air cargo, urban freight, energy intensity and carbon as new institutional and operator data become available. The existence of a research agenda is not a defect in the doctrine; it is the mechanism through which the framework remains testable and improves over time. [R]

Public and institutional validation should be built into the empirical programme. Route economics should be tested with operators; baseline data with responsible public institutions; market assumptions with shippers and enterprises; and governance propositions with the authorities that hold the relevant mandates. Validation does not turn a proposition into proof by consensus; it tests whether the evidence, operating assumptions and implementation responsibilities correspond to reality. [P]

CONCLUSION • THE ECONOMY BEHIND THE MOVEMENT

Africa's freight transition is not principally a question of choosing a cleaner truck, building another railway or reopening a waterway. It is a question of economic architecture. The continent is industrialising, urbanising and integrating markets while still expanding its energy and infrastructure base. The freight system must therefore be designed for the economy Africa intends to build, not only for the economy it inherited.

That changes the hierarchy of decisions. Unproductive movement should be avoided. Necessary movement should be optimised. Suitable freight should be assigned to the mode that performs the complete journey best. Energy should be matched to duty cycle, geography, demand and reliability.

Ports, terminals, borders, urban logistics systems and industrial nodes should be treated as interfaces in one physical economy rather than as isolated assets. Carbon should be measured rigorously, but it should not become the sole measure of success. [P]

The development test is Productive Yield: whether freight systems help create and retain processing capability, stronger enterprises, supplier depth, skills, knowledge, resilience, capital formation and reinvestment. Productive Yield does not excuse poor operating performance. It raises the standard.

A system must still compete on cost, time, reliability, safety and carbon. The additional question is whether those improvements leave behind a stronger economy.

The laboratories in this monograph also show why one continental prescription would be a mistake. Lake Victoria asks whether water can perform a middle mile more effectively than road.

Abidjan-Lagos tests whether short-sea shipping can complement a dense coastal road economy under real cabotage and port conditions. Durban asks how rail recovery, port energy and industrial depth interact. Lobito asks whether a mineral corridor can become more than an evacuation route.

Urban logistics asks whether the city can distribute goods without disabling the movement of people. The framework is common; the answers must remain empirical.

The next frontier is therefore evidence. Operator quotations, route-level cost, dwell distributions, utilisation, energy consumption, emissions, cargo density, access regimes, market structure and value-retention data must increasingly replace broad assumptions. Where the evidence says a proposed modal shift, technology or infrastructure project does not work, the architecture should be capable of saying no. Where it works only under specific demand, regulatory or financing conditions, those conditions should be made explicit.

The metropolitan analysis adds a further conclusion. Freight is one physical expression of a wider circulation system. African cities will increasingly need to coordinate the movement of goods and people with the circulation of money, information and services, while energy enables the physical layers and trust allows shared systems to function. The objective is not to suppress movement or social interaction; it is to increase access, transaction density and productive exchange while reducing avoidable vehicle-kilometres, empty capacity, congestion and energy waste. [P]

This requires metropolitan systems shaped by African economic realities: informality and formal enterprise, physical markets and social commerce, electronic money and cash, high-capacity transit

and demand-responsive mobility, walking and cycling, CEP and traditional freight. Technology should serve this landscape rather than force the landscape to imitate an imported model. [P]

In that sense, the deeper transition is from movement to circulation. Better circulation means that information and payments can move faster, demand can be aggregated before vehicles move, dense passenger and freight flows can use high-capacity trunks, flexible modes can serve the edges, and human-powered movement can remain part of the energy solution where appropriate. More economic and social activity need not require proportionally more physical transport work. [P]

Africa should not merely decarbonise movement, and it should not decarbonise an inefficient freight architecture. It should re-architect circulation so that unnecessary physical movement declines, necessary movement becomes more productive, appropriate modes and energy systems are used, interfaces become more reliable, and the resulting physical economy creates greater productive value with progressively lower resource and carbon intensity.

The quantitative architecture closes the loop between doctrine and decision. Re-architecting freight is not complete when a preferred mode or technology has been named. It is complete only when competing configurations can be compared on common evidence, their trade-offs are visible, their productive additionality is separated from aspiration, and the investment remains credible under uncertainty and disruption. The Productive Freight Decision Model is therefore part of the doctrine itself: a discipline for deciding what to build, what to shift, what to clean, what to defer and what not to build. [P]

The resulting standard is deliberately demanding. A freight proposition must identify the cargo and service need, compare complete routes, establish the counterfactual, show commercial viability, quantify physical energy and carbon on consistent boundaries, demonstrate productive additionality without double counting, expose distributional effects, survive uncertainty and disruption, and preserve an evidence trail that can be tested after implementation. Where the evidence is insufficient, the correct output is not confidence; it is a threshold, a range or a research requirement. [P]

Right freight. Right mode. Right energy. Right infrastructure. Right geography.

Greater Productive Yield.

Annex A. Core metrics and guardrails

The following 21 tools operationalise the architecture. Productive Yield retains the same eight dimensions throughout; each indicator is measured against its defined counterfactual.

A1. The metropolitan congestion relationship

A useful planning relationship developed in the Atlantic work is: $\text{Congestion Cost} \propto \text{Density} \times \text{Freight Volume} \times \text{Infrastructure Gap}$. It is not presented as an econometrically calibrated law. It expresses a systems proposition: as metropolitan density and freight volume rise faster than usable infrastructure and logistics organisation, congestion costs can compound. Road expansion is only one response; consolidation, delivery timing, logistics-node location, wholesale-market design, port release windows, public mobility, land use and data also shape the result.

A2. Value leakage diagnostic

Productive Yield requires an explicit Value Leakage Diagnostic. The diagnostic asks where value exits the productive geography through external processing, imported professional or technical services, imported technology, freight and maritime services, insurance, finance, weak supplier participation, foreign ownership structures or unreinvested profits. Value creation and value retention must therefore be measured separately.

A3. Green Freight four-test framework

Green Freight should be tested through four simultaneous questions: Carbon · Cost · Reliability · Productive Yield. A lower-carbon option that is commercially non-viable, operationally unreliable or developmentally extractive does not satisfy the full freight transition test. Conversely, a commercially attractive option that increases lifecycle carbon or weakens productive capability requires redesign rather than automatic adoption.

A4. Productive energy allocation matrix

Intelligent Energy Allocation is operationalised through a matrix rather than a preferred technology list.

Table 18. Productive energy allocation matrix

Allocation dimension	Required question
Capex	What infrastructure and asset investment is required?
Opex	What is the full operating cost under realistic utilisation?
Availability	Is the energy source physically and commercially available?
Infrastructure	What grid, storage, bunkering, charging or fuel system is required?
Range / duty cycle	Can the technology perform the required operation without distorting service?
Payload	What payload or capacity penalty applies?
Reliability	Can the energy system support required service availability?
Carbon	What is the operational carbon profile?
Lifecycle	What are the upstream, embodied and replacement implications?
Scalability	Can supply, maintenance and infrastructure scale with demand?
Productive Yield	What African capability, value retention and enterprise opportunity result?

Precede the matrix with a geography-and-demand screen:

local energy resource; distance to demand; load profile; offtaker creditworthiness; modular versus permanent infrastructure requirement; connection cost; and transition-dependency risk.

Technology comparison begins only after this screen establishes the operating context.

A5. Energy reliability is carbon credibility

Energy reliability is a freight variable and a carbon variable. Electrified fleets, cold chains, port equipment, rail systems and factories can only deliver their expected operational and carbon performance if electricity is sufficiently reliable. Weak grids can force diesel backup, underutilise electric assets, increase maintenance and undermine nominal emissions gains. Carbon claims should therefore be tested against the actual energy system that supports the asset.

A6. Fossil-Smart maturity ladder

The Fossil-Smart maturity ladder provides a transition sequence without treating earlier percentage thresholds as validated targets:

Table 19. Fossil-Smart maturity ladder

Stage	Condition	Task	Progression gate
1. Fossil-Heavy	High dependence, weak measurement, waste.	Establish baseline and identify waste.	Declared boundary, data owners and reproducible baseline.
2. Fossil Waste Identified	Measured inefficiencies and emission sources.	Eliminate avoidable consumption and operational waste.	Measured hotspots and an executable waste-reduction plan.
3. Fossil-Smart	Measured, efficient and disciplined residual use.	Optimise engines, generation, fuels, routing and operation.	Verified consumption and emission reductions while meeting service requirements.
4. Hybrid Transition	Viable renewables, storage, electrification and cleaner fuels integrated.	Shift suitable applications and protect reliability.	Demonstrated lifecycle performance, reliable integration and viable finance.
5. Future-Ready	Infrastructure preserves technology and fuel options.	Continue reducing lifecycle intensity as economics mature.	Technology optionality and a credible declining absolute-emissions pathway.

Stage 4 was previously termed “Hybrid Decarbonised”. “Hybrid Transition” is the operating description: integration alone does not establish lifecycle decarbonisation. The original aspiration is retained, while performance must be measured. [P]

Fossil-Smart is the discipline across all five stages; Stage 3 denotes demonstrated disciplined residual fossil use. Stage progression requires evidence, service reliability and executable institutional capability; it is not a calendar commitment. Annex F, Table 33, defines the detailed tests. [P]

A7. Carbon Competitiveness measurement family

The Carbon Competitiveness Dashboard should be treated as a family of transparent measures rather than one opaque score.

Table 20. Carbon Competitiveness measurement family

Dashboard measure	Purpose
Grey Carbon Intensity	Embodied carbon intensity of infrastructure and major material choices.
Fossil Waste Index	Avoidable fossil-energy consumption caused by idling, empty running, poor utilisation, waiting and inefficient operations.
Clean Fossil Adoption Score	Adoption of more efficient engines, generation, lower-pollution fuels, hybridisation and operational discipline where fossil energy remains required.
Renewable Penetration Index	Share and functional role of renewable and hybrid energy in relevant freight, port, logistics and industrial systems.
Energy Efficiency Index	Operational and asset energy efficiency using energy/tonne-km, energy/m ³ -km, energy/handled unit and energy/productive value.
Carbon / tonne-km and / m ³ -km	Operational carbon intensity by transport work.
Productive Carbon Yield	Productive value created and retained per unit of lifecycle CO ₂ e.
Green Port / SEZ Compliance Score	Performance against agreed energy, carbon and productive-transition standards for port and industrial-zone systems.

Operating specification: declare units, denominators, measurement windows, accounting boundaries, source versions, allocations and input maturity for every measure. Show absolute emissions alongside intensity and Productive Carbon Yield. Annex F, Table 34, provides the auditable Durban specification; composite indices require published components and weights before a score is claimed. [P]

A8. Corridor Carbon Productivity and Productive Carbon Yield

Corridor Carbon Productivity was an earlier formulation focused on economic value generated per unit of carbon emitted. The concept evolved into Productive Carbon Yield because gross economic value can obscure where value is created, owned and retained. Productive Carbon Yield therefore asks how much productive value is created and retained per unit of lifecycle CO₂e. It complements rather than replaces absolute emissions and emissions-intensity accounting.

A9. Integrated performance hierarchy



Report all nine layers; throughput alone is not the development outcome.

Figure 16. Integrated Performance Hierarchy

Freight performance should be read through a hierarchy rather than one KPI:

Table 21. Integrated performance hierarchy

Performance layer	Examples
Operational	Transit time, dwell, schedule adherence, utilisation, empty running and handling productivity.
Physical	Tonnes, m ³ , TEU, units, tonne-km and m ³ -km.
Energy	Fuel, electricity, energy/transport work and energy/productive value.
Carbon	Operational, system, Grey/embodyed, lifecycle and carbon/transport work.
Economic density	Value/tonne, value/m ³ , inventory and working-capital effects.
Productive depth	Processing stage, domestic supplier layers, skills, technology and enterprise capability.
Retention	Margins, ownership, domestic procurement, tax base and capital formation.
Resilience	Substitutability, disruption response and recovery performance.
Productive Yield	Transformation; Enterprise; Capability Development; Retention; Market Access; Spatial Diffusion; Resilience; Compounding.

A10. Modal redundancy and recovery

Modal redundancy counts capacity that can actually substitute under the specified disruption. $MRF = \text{usable alternative modal capacity} / \text{normal throughput over the same period, with matched cargo and service requirements}$. Verify permissions, activation time, capacity commitments and cost. Thresholds are corridor- and commodity-specific propositions, not validated continental rules.

Recovery Throughput Factor compares throughput restored within a defined window with normal throughput in an equal-duration reference window. Recovery time, rerouted share, production protected, critical deliveries and inventory shortfall avoided are reported separately. [P]

Disruption playbooks should specify alternative routings, modes, nodes, activation triggers, institutional responsibilities, commercial arrangements and capacity limits before a shock occurs.

A11. Authored Transition and transition-dependency risk

An Authored Transition means African institutions and enterprises determine appropriate technologies, productive-energy pathways, climate-finance uses and environmental stewardship in response to African economic conditions rather than importing a transition template unchanged.

The transition-dependency test asks whether a lower-carbon freight system deepens dependence on imported equipment, software, finance, fuels, batteries, control systems or maintenance. The local-value-addition question should therefore be asked for solar, batteries, hydrogen, charging, alternative fuels, shore power and digital systems: what can African economies manufacture, engineer, operate, maintain, finance, adapt, reuse or recycle?

A12. Food-system freight and post-harvest loss

Food freight begins with production, aggregation, grading and cooling. It connects first transformation, processing and packaging with wholesale, urban consumption or export.

harvest loss is partly a logistics and energy failure: poor storage, handling, cold-chain reliability, market access and transport can destroy productive value before the product reaches demand.

Agricultural first transformation near source can change mass, volume, value density and shelf life where economics support it.

A13. Productive Freight Decision Model - minimum data dictionary

Table 22. Productive Freight Decision Model data dictionary

Family	Minimum fields	Unit / form
Movement	Origin, destination, distance by leg, mode, commodity/cargo, mass, volume, load unit, shipment size and frequency; production territory, industrial node, border, port and market.	km; t; m ³ ; units; trips/year
Service	Transit-time distribution, dwell, waiting, service frequency, schedule adherence, reliability, utilisation, loss, damage and spoilage.	Hours/days; % on-time
Cost	Dated line-haul and complete-route quotes with inclusion schedules; access/drayage and first/last mile; terminal/handling, storage, border/compliance, inventory, insurance, reliability, energy, empty return and administration. Avoid duplicate charges.	Currency/shipment, /t or unit
Productive Density	Cargo value and value band; domestic value retained; processing stage; mass/volume; perishability and handling constraints.	Currency/t, /m ³ ; stage
Productive Yield	Baseline, scenario/intervention and counterfactual outcomes for all eight canonical dimensions, with attributable physical and monetary measures where defensible.	Native units; monetary where defensible
Energy	Fuel/electricity by leg and node; energy source; facility energy; utilisation; asset duty cycle.	MJ, kWh, litres; per transport work
Carbon	Operational and lifecycle boundary; emission factors; GHG by leg/node; material Grey Carbon and embodied assets where relevant.	kgCO ₂ e; kgCO ₂ e/t-km; kgCO ₂ e/m ³ -km
Resilience	Usable alternative capacity, dependency, shock type, retained service, activation time, recovery time/window and shock loss.	% throughput; hours/days; currency
Capital	Capex, opex, asset life, utilisation ramp and financing terms where applicable.	Currency; years; %
Evidence	Source, date, geography, claim-status marker, input maturity, confidence/range, units and provenance.	Claim marker; citation; input state
Asset	Vehicle/vessel/wagon type, capacity, age, duty cycle and empty-return behaviour.	Type; payload/capacity; years; duty cycle; empty-return share

Data ownership and collection responsibilities are assigned in the Chapter X minimum dataset. Currency, price year and exchange-rate convention must accompany monetary fields.

A14. Scenario-comparison protocol

1. Define the decision, cargo/value chain, origin-destination pair, service requirement, baseline year and appraisal horizon. 2. Specify the do-minimum baseline before designing alternatives. 3. Hold cargo and service assumptions constant unless the scenario intentionally changes the productive form of the cargo. 4. Calculate TRC in native commercial units. 5. Calculate physical movement,

energy and carbon on common boundaries. 6. Measure Productive Yield as additionality against the same counterfactual. 7. Test resilience under defined disruptions. 8. Apply feasibility gates and dominance tests. 9. Run sensitivity and stress tests. 10. Report unresolved [R] inputs and the threshold at which the decision changes. [P]

A15. Guardrails against double counting and false precision

Do not count the same benefit twice across TRC, economic appraisal and Productive Yield. Do not monetise institutional capability merely to force comparability. Do not treat source-reported projections as observed outcomes. Do not convert an uncertain causal attribution into a precise Productive Yield number. Do not compare carbon ratios with different system boundaries. Do not assume modal shift automatically creates productive additionality. Do not assume a lower-carbon asset produces a lower-carbon system when utilisation, energy source, empty running, interfaces or induced movement reverse the result. [P]

A16. Evidence Sufficiency Gate

For each material variable record: value; unit; period; system boundary; source; input maturity (Measured / Reconciled / Estimated / Scenario / Unknown); claim status where relevant ([E] / [SR] / [P] / [S] / [R]); sensitivity range; and whether the variable can reverse the decision. A preferred scenario should not be declared where an Unknown decision-critical variable remains unresolved. [P]

A17. Counterfactual and attribution protocol

Define the do-minimum counterfactual before the intervention case. Separate direct user benefits, wider economic effects and Productive Yield outcomes. Record the causal pathway for each claimed productive effect; identify complementary policies; state the attribution method; and downgrade causal language where evidence supports only association or contribution. Benefits already monetised in CBA must not be counted again inside Productive Yield. [P]

A18. Time-horizon and discounting protocol

Report construction, operational stabilisation, productive response and long-run/lifecycle horizons separately. Discount monetised financial and economic flows under the applicable appraisal convention; retain undiscounted physical trajectories for movement, energy and carbon. Test delayed demand, delayed complementary investment and slower productive response where they can alter the decision. [P]

A19. Distributional incidence matrix

For each scenario, identify material gains, costs and risks across shippers; carriers/logistics providers; workers; consumers; domestic suppliers; communities; cities/territories; and government. Add gender, income, firm-size or geographic disaggregation where material. Record whether a complementary measure is required to prevent exclusion, displacement or enclave capture. [P]

A20. Reproducibility and ex-post evaluation protocol

Archive the baseline dataset, model version, formulas, scenario definitions and evidence register before approval. After implementation, compare forecast and actual TRC, utilisation, reliability, energy, carbon and Productive Yield indicators at defined intervals. Publish material forecast error

and explain whether it arose from demand, cost, delivery, behaviour, policy, shock or attribution assumptions. Use the result to recalibrate subsequent applications. [P]

A21. Water Corridor Decision Gate

Table 23. Water Corridor Decision Gate

Gate	Required question
Physical	Is the waterway reliably navigable for the required vessel and service?
Demand	Is there sufficient recurring cargo/passenger demand?
Cargo	Is the freight technically and economically suited to water?
Service	Can frequency and reliability meet market requirements?
Interface	Can modal-transfer cost, dwell and handling be controlled?
Connectivity	Are first/last-mile road, rail and border connections adequate?
Commercial	Does Total Route Cost outperform realistic alternatives?
Institutional	Can navigation, customs, safety and cross-border governance function?
Environmental	Are ecological and hydrological impacts acceptable and resilient?
Investment	Can infrastructure, fleet and operations be financed sustainably?
Productive	Does the intervention generate additional Productive Yield?

Navigability is necessary but not sufficient. Commercial viability is necessary but not sufficient. The final developmental question is whether the resulting movement system strengthens the productive economy.

Annex B. Reproducing the numerical illustration

This is a calculation ledger, not an operator dataset. Currency is illustrative constant 2026 US dollars; these assumed figures are not current quotations or a market-price comparison. All inputs have Scenario maturity. Rounding appears only in presentation. Here k is the inventory cost per day, w is departure waiting in days, and u is vessel utilisation relative to the reference allocation. Evaluate the symbolic formulas from their stated inputs and round only the displayed results to two decimal places. Do not reuse rounded coefficients in later calculations. The 50.25% carbon-parity value is rounded from the underlying ratio; a value displayed as 0.50 is not an exact pass threshold.

Table 24. Reproducing the numerical illustration

Calculation	Formula and displayed result
Inventory cost / day	$k = 40,000 \times 0.20 / 365 \approx \text{US\$}21.92/\text{day}$
Road TRC	$R = 1,600 + 100 + 3.5k + 120 \approx \text{US\$}1,896.71$
Lake elapsed days	$d(w) = 0.5 + 0.75 + 0.25 + w = 1.5 + w$
Lake TRC	$L(w) = 900 + 300 + 160 + 80 + (80 + k)(1.5 + w) + 80$; $L(1) \approx \text{US\$}1,774.79$
Lake intercept and slope	$L(w) = L(0) + (80 + k)w$; displayed coefficients: $\text{US\$}1,672.88 + \text{US\$}101.92w$
Waiting at parity	$w^* = [R - L(0)] / (80 + k) \approx 2.20 \text{ days}$
Ferry quote ceiling, $w = 1$	$900 + R - L(1) \approx \text{US\$}1,021.92$
Road energy	$400 \times 36 + 20 \times 3.6 = 14,472 \text{ MJ}$
Lake energy	$(80 + 160) \times 36 + 30 \times 3.6 = 8,748 \text{ MJ}$
Road GHG	$400 \times 3.2 + 20 \times 0.5 = 1,290 \text{ kgCO}_2\text{e}$
Lake GHG utilisation stress	$80 \times 3.2 + 30 \times 0.5 + 160 \times 3.2/u = 271 + 512/u$
Carbon parity utilisation	$u^* = 512 / (1,290 - 271) \approx 0.50 \text{ (50.25\%)}$

Reproduce both cost and service constraints. Sensitivities are conditional: a change in utilisation can alter sailing frequency, tariff, allocated energy and waiting simultaneously. Estimate their joint distribution from operations rather than treating isolated sensitivities as an investment case.

Annex C. From public evidence to empirical validation

A bounded evidence register

Table 25. Bounded evidence register

Evidence carried from the manuscript	What it supports	What it does not establish
PIDG/EAMT: vessel capacity and 18-hour crossing	A reported service configuration and sailing leg.	Matched door-to-door tariff, utilisation, delays or reliability.
Kisumu: 496,516 tonnes in 2025	Reported aggregate port activity.	Cargo available to a specified ferry or a reliable growth percentage.
Mombasa: import, export and transit totals	Gateway scale and directional asymmetry.	Container empty returns, matched backhaul or productive additionality.
World Bank/EAC 2015 water charge and nodal cost	Historical modelling reference.	Current RoRo quotes or comparable handling structure.
Lobito 2026 appraisal and financing	Programme design and financing commitments.	Delivered rail capacity, agricultural diversification or retained value.

Matched-shipment collection protocol

Recruit cargo owners and competing operators before selecting a preferred configuration. Define matched origins, destinations, commodity, quality, mass/volume, shipment value, direction and service requirement. Obtain dated binding quotes and inclusion schedules; reconcile them with invoices and actual payments. Preserve all dispatched, deferred and cancelled shipments so the sample does not contain only successful sailings.

Record collection, terminal arrival, loading, departure, arrival, release and final-delivery time stamps. Measure fuel/electricity, vessel/truck loads, return utilisation and allocated node consumption. Observe variability across seasons, congestion states and directions. Choose sample size from observed variance, the effect size that matters to the decision and the required confidence; do not invent a universal minimum shipment count.

Productive outcomes and identification

Pre-register the baseline, counterfactual, complementary interventions and eight dimension-level indicators. Use firm procurement, processing, skills, retained GVA, ownership, market reach, spatial participation, shock protection and reinvestment records. Where feasible select credible comparison firms/geographies and test pre-intervention trends. Separate observed association, contribution and defensible causal attribution. Record the effect of power, skills, finance, access and industrial land rather than allocating their entire outcome to freight.

Carbon, shocks and replication

State operational versus lifecycle boundaries, energy factors, allocation, empty returns, upstream and embodied exclusions. Model usable alternative capacity with actual activation rights and committed service. Test hydrological interruption, missed sailing, road closure, port delay and energy disruption. Publish an anonymised input dictionary, transformations, formulas, versions and a replication log; protect commercially confidential fields through aggregation rather than concealing calculation rules.

Independent technical review before a decision-grade claim

A transport economist should review cost boundaries and appraisal; an operator/port or naval specialist should review service and capacity; an emissions specialist should review energy, allocation and lifecycle scope; a development economist or causal evaluator should review Productive Yield and identification. Ask each to document assumptions, objections and unresolved evidence. This edition specifies the review requirement; it does not claim that external peer review or operator validation has occurred.

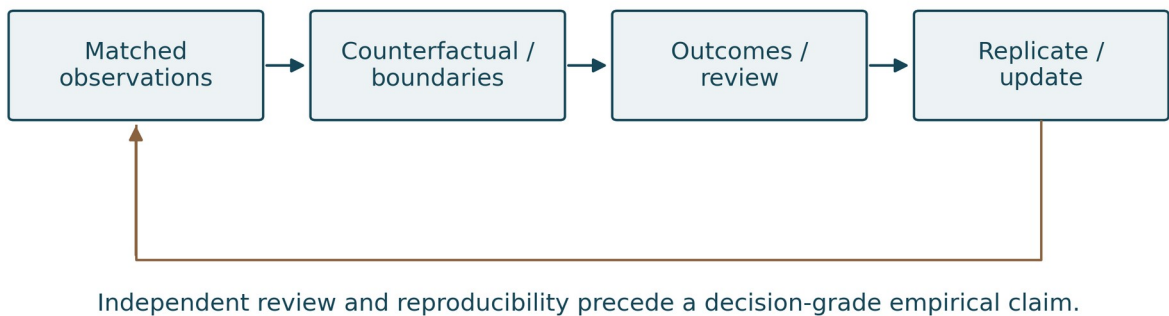


Figure 17. Empirical Validation and Feedback

Annex D. Applying the model to published completion evidence

A bounded Abidjan-Lagos application

The World Bank's 18 December 2019 completion report, ICR00004935, paragraph 8 (printed pp. 7-8), summarises APL1 closing results. Togo closed in September 2016; Ghana and Benin in June 2017. These are historical source-reported indicators, not current corridor observations. [SR; N40]

Table 26. Abidjan-Lagos reported completion indicators

Reported indicator	Baseline	Closing result	Reduction, calculated
Lomé port dwell	18 days	9 days	9 days; 50.0%
Cotonou port dwell	19 days	14 days	5 days; 26.3%
Ghana-Côte d'Ivoire border	24 hours	20 hours	4 hours; 16.7%
Togo-Benin border	24 hours	10 hours	14 hours; 58.3%
Benin-Nigeria border	48 hours	31 hours	17 hours; 35.4%

Calculation: $(\text{baseline} - \text{closing result}) / \text{baseline} \times 100$. Percentages above use the published endpoints, rounded to one decimal. Indicators describe different nodes and units; they cannot be added into a single matched-shipment transit saving. The source attributes results to the programme, but these endpoints alone do not identify a causal counterfactual. [SR/P; N40]

What the six engines can conclude

Table 27. What the six engines can conclude

Decision engine	Conclusion permitted here	Evidence still needed
Total Route Cost	Less reported dwell or border time can lower time-related costs. No currency saving is computed.	Matched shipments, inclusion schedules, cargo value, inventory rate, detention and variability.
Productive Density	No processing-depth or value-density effect is established.	Commodity, value, mass/volume and processing-stage records.
Productive Yield	A potential Market Access mechanism is visible; the eight dimensions remain unquantified.	Firm-level outcomes and credible counterfactuals for each dimension.
Energy Productivity	No energy-saving inference follows from elapsed time alone.	Fuel/electricity by leg and node, engine state and transport work.
Carbon Performance	No emissions result or Productive Carbon Yield ratio is established.	Matched energy, factors, allocation, lifecycle scope and attributable retained GVA.
Resilience Performance	Lower average delay does not measure shock protection or recovery.	Distribution tails, shock observations, executable alternatives and recovery windows.

Productive Yield: eight explicit tests

Table 28. Productive Yield evidence requirements

Dimension	Mechanism to investigate	Required outcome test
Transformation	Reliable inputs may support deeper processing.	Processing-stage change versus comparable firms.
Enterprise	Access may widen qualified supplier participation.	Contracts, procurement and firm graduation.
Capability Development	More reliable activity may support skills formation.	Training, certifications and reproducible technical capability.
Retention	Lower friction may change retained margins and working capital.	Incremental domestic GVA and ownership/income incidence.
Market Access	Reported time improvement is a plausible access mechanism.	Delivered cost, market reach, frequency and diversification.
Spatial Diffusion	Interface reform may spread benefits across connected nodes.	Participation beyond gateway enclaves.
Resilience	More predictable interfaces may protect production.	Output protected, usable substitution and recovery.
Compounding	Retained gains may finance subsequent capability.	Repeat investment and additional reinvestment over time.

The table is an investigation agenda [P/R], not eight findings. Each proposition needs a baseline, an indicator, a comparison and an attribution design. Unknown outcomes remain unknown; they are neither assigned zero nor inferred from throughput.

Decision and replication

This evidence supports a bounded conclusion: interface reform is a credible candidate for investigation before committing to new capacity or modal substitution. It does not establish that road, water or rail is superior, that all reported time gains accrue to the same consignment, or that productive additionality has been demonstrated. The model's useful output here is the next evidence requirement.

A replication file should retain the five published endpoints, their locations and units, the source paragraph, the closing periods and the formula above. Shipment-level verification then follows Annex C. Compare seasonal distributions and matched consignments before estimating commercial benefits; trace who captures those benefits before crediting retained value. This separation makes the architecture falsifiable: operational improvement can be confirmed while a productive-transformation claim remains unproven.

Source consistency: the Kisumu diagnostic

KPA's reported Kisumu inputs illustrate why reconciliation is part of the architecture. The published endpoints 496,516 and 295,516 imply an increase of 201,000 tonnes and approximately 68.0%, rather than the release's stated 163,085 tonnes and 55.0%. These calculations diagnose inconsistency; they do not certify a corrected historical series. Accordingly, only the reported 2025 tonnage is used in the laboratory, and no growth-based decision is made until KPA reconciles the baseline. [SR/P; N29]

Annex E. Validation status of the six engines and eight dimensions

The six-engine model and eight-dimension Productive Yield framework are specified analytical instruments. This edition checks their internal calculations, boundaries and evidence requirements. It does not claim full empirical validation. The Lake Victoria illustration uses Scenario inputs; the historical Abidjan-Lagos application contains published operational endpoints but no matched six-engine dataset or causal eight-dimension evaluation. Neither application establishes a preferred investment configuration.

Six-engine assessment

Table 29. Six-engine validation assessment

Engine	Check completed and permitted interpretation	Evidence needed for empirical validation
Total Route Cost	Arithmetic checked: road US\$1,896.71; lake US\$1,774.79; saving US\$121.92 at one-day waiting. Cost parity at 2.20 days; four-day service gate permits 2.5 waiting days. [S]	Current matched quotes, invoices, inclusions, detention, delays and loss distributions. Retain as a conditional cost model.
Productive Density	US\$40,000 / 20 t = US\$2,000/t; US\$40,000 / 50 m ³ = US\$800/m ³ . Same cargo and processing stage: no transformation gain follows from modal change alone. [S]	Actual cargo values, mass/volume, processing stages and a consistent retained-value definition. Retain as a measurement framework.
Productive Yield	The US\$40,000 retained GVA, four technicians and three suppliers belong to a separately assumed complementary programme. No attributable effect is established for any of the eight dimensions. [S/R]	Dimension-specific baselines, comparison outcomes, complementary-intervention records and attribution design. Retain as an additionality framework.
Energy Productivity	Road 14,472 MJ; lake 8,748 MJ. Work intensities: 1.382 and 1.143 t-km/MJ. Lower shipment energy coexists with lower transport-work productivity because route lengths differ. [S]	Metered fuel/electricity, load allocation, node activity, return movements and matched service. Retain as a bounded energy accounting framework.
Carbon Performance	Limited fuel/electricity inventory: road 1,290 kgCO ₂ e; lake 783 kgCO ₂ e. At utilisation u = 0.5, lake is 1,295 kgCO ₂ e; parity u = 0.5025. These are scenario outputs, not lifecycle findings. [S]	Observed energy and allocation, justified factors, upstream/embodyed scope and attributable retained GVA for Productive Carbon Yield. Retain as an accounting framework.
Resilience Performance	A 14-day outage, 30% alternative capacity and 48-hour activation are assumptions. MRF would be 0.30 only under matched windows and executable capacity; recovery throughput cannot be calculated from these assumptions alone. [S/R]	Committed substitute capacity, rights, activation, compatibility, shock histories and recovery-window throughput. Retain as a stress-testing framework.

Eight-dimension assessment

Table 30. Eight-dimension validation assessment

Dimension	Current evidence status	Required empirical test
Transformation	No observed attributable processing-stage or capacity change.	Measure local processing share and first/secondary output against a comparison.
Enterprise	Three suppliers are a complementary-programme assumption.	Verify contract number/value, local procurement share, firm graduation and service depth.
Capability Development	Four technicians are assumed; completion and reproducible capability are unobserved.	Verify training completion, certification, skilled work and maintenance capability against baseline.
Retention	US\$40,000/year retained GVA is assumed, with no observed causal incidence.	Reconcile domestic GVA, margins, ownership/income, tax base and reinvestment without double counting.
Market Access	Historical node delays provide a possible mechanism, not an attributable market-access outcome.	Observe delivered-cost reduction, reachable markets, service frequency and export diversification.
Spatial Diffusion	No observed spread beyond the gateway or enclave.	Track connected productive nodes, secondary-city participation and supplier locations.
Resilience	The alternative-capacity scenario does not establish protected productive output.	Observe output protected, substitution, recovery and inventory shortfall avoided.
Compounding	No longitudinal reinvestment or subsequent capacity dataset.	Measure reinvestment rate, repeat investment and new firms/capacity from retained income and knowledge.

Publication claim and decision boundary

All six engines and all eight dimensions remain in the framework. The scenario arithmetic is reproducible; the empirical outcomes remain unvalidated. Unknown is a research status, not a zero score. Do not aggregate the eight dimensions into an unearned impact total or infer transformation from throughput, time savings or lower modelled emissions. A decision-grade application requires the matched collection, counterfactual, accounting and independent-review protocols in Annex C. This publication contributes a specified and testable framework, rather than a certified demonstration of corridor impact.

ANNEX F. DURBAN AND THE NORTH-SOUTH CORRIDOR: IMPLEMENTATION PROTOCOL

F1. Purpose, status and energy workstreams

This annex translates the Durban laboratory in section 77 into a proposed implementation protocol. It draws on Fossil-Smart, Future-Ready Corridors: Durban and the North-South Corridor. The source report was prepared by the author through LOGI-CONSULT; its proposals are therefore presented as authored propositions [P] and are subject to the same evidence protocol as all other claims in this monograph. The zones, programmes, gates and institutional arrangements below are proposals [P], not adopted mandates, funded projects or demonstrated corridor outcomes. The baseline protocol specifies data still to be collected; programme titles do not establish an operating institution or financing facility. These proposals extend the existing economic architecture and retain the six-engine and eight Productive Yield dimension validation boundaries in Annex E.

This is a worked implementation example for the monograph's pan-African framework. The other eight laboratories can adapt its sequence of intervention zones, work packages, baselines, progression gates, governance responsibilities and financing tests. Their boundaries, institutions, cargo flows, energy conditions and evidence must be established locally; Durban's specific interventions and numerical context are not transferred unchanged. [P]

As an overall discipline, Fossil-Smart combines reliable productive services with measured reductions in avoidable fossil consumption and lifecycle emissions. Stage 3 denotes demonstrated disciplined residual fossil use within that wider transition. Residual fossil use is tested against efficiency, credible alternatives and an explicit transition pathway. Fossil-Smart does not certify fossil dependence as clean, and an improvement in emissions intensity does not by itself demonstrate falling absolute emissions. [P]

Six energy workstreams within the existing architecture

Energy security and fossil discipline: reliability, efficient residual fuel use, backup generation and operating practice.

Logistics efficiency and modal optimisation: avoidable movement, queues, empty running, consolidation and viable modal rebalancing.

Renewable, hybrid and resilient energy: suitable electrification, storage, renewable supply and reliable integration.

Digital carbon intelligence: traceable measurements, allocation, source versions and decision-grade MRV.

Grey Carbon and circular infrastructure: whole-life procurement, material choices, repair, reuse and asset longevity.

Transition finance and carbon-linked investment: finance structures matched to executable projects and verified performance.

The six energy workstreams apply the energy architecture in section 45. They remain distinct from the six decision engines and the six Economic Operating System (EOS) layers. The EOS layers are Physical, Industrial, Trade, Digital, Capital and Governance. For this protocol, Physical concerns assets and interfaces; Industrial concerns production and transformation; Trade concerns market access and commercial flows; Digital concerns data and coordination; Capital concerns financing and investment; and Governance concerns mandates, rules and accountability. Assess the workstreams through the eight Productive Yield dimensions in Table 9. [P]

F2. Five geographical intervention zones

Interventions should follow the freight movement and its industrial relationships from the port through the logistics basin, the inland spine and cross-border nodes. No zone is treated as an isolated infrastructure project. Each requires an accountable operator, a feasible service proposition and a decision-grade baseline. [P]

Table 31. Durban–North–South Corridor intervention zones

Zone and operating interface	Priority intervention and acceptance test
Port / Bayhead / Maydon Wharf	Measure berth, gate, equipment, reefer and backup-energy demand; reduce queues and terminal dwell; test equipment electrification, hybrid systems, renewable supply and shore-power feasibility. Compare whole-life expansion options. Accept only options compatible with vessel demand, power reliability and measured service performance.
Durban logistics basin / Cato Ridge / Hammarsdale	Coordinate staging, warehouses, cold chains, distribution and truck movements. Test consolidation, solar and storage, efficient buildings and lifecycle-qualified fuels. Demonstrate reduced avoidable kilometres and waiting without transferring congestion or cost to smaller operators or neighbouring communities.
N3 Durban–Gauteng freight spine	Test rail recovery against commodity, origin–destination, terminal and service requirements. Improve truck utilisation, scheduling and driving practice. Compare door-to-door reliability, total delivered cost, absolute emissions and emissions per tonne-kilometre.
Gauteng inland gateway	Coordinate inland intermodal terminals, industrial users and freight consolidation. Test renewable supply and interoperable data. Demonstrate a viable service, stronger local production linkages and enforceable access arrangements, rather than capacity construction alone.
Cross-border North–South Corridor	Address border delay, diesel dependence and fragmented data through executable clearance reform, harmonised MRV and suitable node energy or charging arrangements. Test rail and other service options against operating rights, institutional capacity and matched cross-border flows.

Zone boundaries and coverage must be declared before measurement. North–South Corridor here denotes the connected cross-border freight system; it does not imply that every segment shares Durban’s electricity, operating conditions or institutional capability. [P]

F3. Eight proposed implementation programmes

The portfolio comprises eight testable work packages. Each requires an accountable sponsor, operating authority, budget, data access and an explicit activation test. [P]

Table 32. Durban implementation programme portfolio

Programme	Work package and decision output
P1. Corridor carbon baseline	Reconcile operational emissions and relevant Scope 1, 2 and 3 boundaries across defined flows and nodes; record asset embodied emissions separately. Publish exclusions, allocations, factors, maturity states and double-counting controls.
P2. Flow and idle reduction	Test appointments, staging, coordinated terminal access and dwell reduction. Report waiting, loaded and empty movement, total fuel use and service reliability against a comparable baseline.
P3. Rail recovery by cargo and route	Identify addressable commodity and origin–destination flows; test timetable, capacity, terminal, handling and access conditions. Advance only a service that can meet shipper requirements and institutional gates.
P4. Node energy resilience	Assess solar, storage, wheeling, efficient backup and critical-load microgrids against outage exposure, tariffs, capacity and lifecycle factors. Demonstrate reliable energy for freight and productive activity.
P5. Grey Carbon procurement	Screen major capital works for whole-life carbon and cost; require traceable materials passports. Compare refurbishment, reuse, design life and maintenance with new construction before procurement.
P6. Fuel and technology testbed	Test fuels and equipment for applications where direct electrification is impractical. Include upstream emissions, methane leakage where relevant, fuel supply, maintenance and operating reliability before making a lifecycle claim.
P7. Carbon MRV and decision platform	Build auditable data exchange before complex modelling. Use digital twins only where data quality and a defined decision justify them. Map ISO 14083 / GLEC accounting to applicable reporting requirements without an additional mandatory certification layer.
P8. Transition finance packaging	Develop a proposed project-preparation and finance facility, subject to mandate and capital availability. Match instruments to cash flow and risk; distinguish proposed, committed and disbursed finance and verified delivery.

F4. Maturity progression and release gates

Table 19 retains the five-stage Fossil-Smart ladder and the name Hybrid Transition. Fossil-Smart is the discipline across all five stages; its Stage 3 denotes demonstrated disciplined residual fossil use. Progression is evidence-based, not calendar-based. A stage requires its measurement, service, institutional and financing conditions to be demonstrated; an Unknown decision-critical input prevents unconditional progression. The following gates operationalise that ladder. [P]

Table 33. Evidence required for Fossil-Smart stage progression

Stage	Evidence and progression gate
1. Fossil-Heavy	Declare assets, flows, energy sources, service requirements and accounting boundaries. Assign data owners and establish a reproducible baseline with documented gaps. Progress only when principal consumption and waste sources can be measured or explicitly bounded.
2. Fossil Waste Identified	Identify idling, empty running, inefficient generation, unnecessary kilometres and other hotspots using matched operating data. Establish counterfactuals and avoid shifting waste outside the measured boundary. Advance after feasible waste-reduction measures and an accountable delivery plan are approved.
3. Fossil-Smart	Demonstrate measured reductions in avoidable consumption and emissions over a declared comparable period, while meeting reliability, safety and productive-service requirements. Disclose residual dependence and assess viable alternatives. A fuel label or equipment purchase is insufficient.
4. Hybrid Transition	Verify the performance of renewables, storage, electrification or cleaner fuels within the declared lifecycle boundary. Demonstrate reliable integration, executable operating arrangements and a sustainable finance plan. Integration alone is not evidence of decarbonisation.
5. Future-Ready	Preserve technology and fuel optionality while delivering productive value, repeatable MRV and a credible trajectory for declining absolute lifecycle emissions. Test the pathway under demand growth and asset replacement. Rising value per unit of carbon does not excuse an unreported increase in absolute emissions.

Carbon attribution and procurement safeguards

System-induced carbon is an attribution and diagnostic view of operational emissions arising from congestion, empty running, waiting and spatial design. It is not a third additive inventory. Report operational emissions once within the declared boundary; disclose how system causes are attributed. Combine embodied and operational emissions only across compatible lifecycle periods and without counting a source twice. [P]

Major procurement comparisons should declare the functional service, asset life, construction, operation, maintenance, replacement and end-of-life assumptions. Materials passports should identify quantities, origin, declared emission factors or verified product declarations, provenance, reused content and reuse or recovery options. Do not apply a universal embodied-carbon percentage to every asset. [P]

F5. Dashboard units, boundaries and reporting rules

Table 20 remains a measurement family. The following operating specification supplies auditable units and denominators. Every entry requires an owner, reporting period, boundary, source version, allocation method and maturity state. Show absolute emissions alongside intensity; keep targets distinct from observed results. [P]

Table 34. Durban dashboard operating specification

Measure	Unit and denominator	Boundary and reporting rule
Freight GHG intensity	g CO2e per tonne-km	Report by mode and origin–destination; declare loaded transport work, allocation and lifecycle scope; show absolute totals.
Rail share of addressable freight	% tonnes; or % tonne-km	Define eligible cargo and routes first; report mass and transport-work shares separately.
Truck waiting and idling	Minutes per call / visit	Define node, queue boundary and observation window; distinguish elapsed waiting from engine-on idling.
Empty running	% vehicle-km	Empty vehicle-km divided by total vehicle-km within the declared fleet / flow boundary.
Port energy intensity	kWh per TEU or handled tonne	Declare equipment and terminal coverage; use consistent energy conversion and keep container and bulk denominators separate.
Renewable energy share	% of node energy consumed	State electricity-only or all-energy scope; document contracted / wheeled supply and attribute certificates once.
Electricity emission factor	kg CO2e per kWh	State location-based / market-based method, source year and supply boundary; do not substitute national mix for verified node supply.
Grey Carbon intensity	kg CO2e per functional unit	Declare comparable service, design life and embodied stages; preserve total embodied emissions separately.
Whole-life capex screening	% major projects screened	Define major-project threshold; disclose both count and capital-value coverage, with completed assessments.
Productive Carbon Yield	Retained productive value per t CO2e	Define value currency / price year, retention attribution and lifecycle denominator; report absolute emissions alongside yield.
Verified MRV coverage	% priority flows / nodes covered	State denominator, weighting and verification basis; do not count unverified estimates as verified coverage.
Transition finance mobilised	Rand or USD, dated	Separate proposed, committed and disbursed amounts; disclose exchange-rate date and avoid counting the same capital twice.

The Fossil Waste Index, Clean Fossil Adoption Score and Green Port / SEZ Compliance Score require published component definitions and weights before any composite score is claimed. Descriptive adoption or compliance cannot replace measured energy, carbon or productive outcomes. [P]

F6. Baseline collection and reconciliation protocol

The baseline must be reproducible at the operating interface, not inferred from continental averages. Record collection frequency and observation window, sampling coverage, missingness, calibration, reconciliation and uncertainty. Keep Measured, Reconciled, Estimated, Scenario and Unknown inputs distinguishable. [P]

Table 35. Baseline collection responsibilities and minimum records

Dataset	Minimum collection and reconciliation requirement
Port and terminal energy	Meter electricity by period and relevant equipment; record fuel quantities and duty cycles, including tugs, reefers and backup generation. Reconcile meter / invoice totals to equipment records and declare unallocated consumption.
Truck movement and service	Capture counts, origin–destination, load, loaded / empty vehicle-km, queue and engine-on waiting, service time and fuel. Match journeys to port / node visits; disclose sample coverage and representativeness.
Rail service and addressable cargo	Collect commodity and route tonnes, train / terminal capacity, service frequency, transit-time distribution, cancellations, handling and access conditions. Match comparable door-to-door road and rail movements.
Electricity and node resilience	Record node supply, outage duration, critical loads, time-specific consumption, contracted / wheeled energy and emission factors with their versions. Retain a separate account of backup fuel and losses.
Embodied and whole-life assets	Record material quantities and declarations, refurbishment / new-build alternatives, asset life, construction energy, maintenance, replacement and end-of-life assumptions. Reconcile materials passports to procurement and design records.
Municipal and industrial interfaces	Map relevant local inventories and industrial energy users to compatible periods, sectors and boundaries. Declare overlaps and exclusions; do not sum municipal and operator inventories indiscriminately.
Investment alternatives	Collect comparable capex, opex, tariff, financing currency, useful life, service, reliability and lifecycle-carbon assumptions. Apply bankability and institutional gates and disclose scenario sensitivity.

Collection before targets

A technical secretariat should maintain the data dictionary and reconciliation log under an agreed mandate. Operators retain responsibility for their records; the designated reviewer assesses methods, exclusions and material uncertainty. Set numerical corridor targets only after a defensible baseline and feasible delivery pathway exist. [P]

F7. Governance, annual reporting and pilot activation

A proposed corridor compact should coordinate existing mandates before creating additional bodies. Establish a small technical secretariat only with an accountable host, staffing, budget, data-access authority and dispute-resolution process. Institutional capability remains an explicit feasibility gate. [P]

Table 36. Proposed governance responsibilities

Responsible actor	Required responsibility and authority test
National transport and energy authorities	Align freight, rail access, energy and reporting rules; identify approvals and enforceable authority. Resolve conflicting mandates and test policy implementation capacity.
Transnet and relevant port / rail operators	Own operational delivery, access interfaces, maintenance and service data within their mandates. Publish declared capacity and reliability assumptions and accountable improvement plans.
eThekweni and provincial authorities	Coordinate land use, road access, staging, local infrastructure, permitting and relevant inventories. Test budget and enforcement capacity and community impacts.
Road, logistics and industrial operators	Provide agreed operating records, implement suitable pilots and confirm service requirements. Include smaller operators and avoid inaccessible reporting or procurement conditions.
Finance institutions and project sponsors	Evaluate cash flow, currency exposure, execution capability and eligible expenditure; separate commitments from disbursements and link performance terms to verifiable baselines.
Cross-border authorities and partners	Demonstrate executable clearance, access and data-sharing arrangements. Assign authority for disputes, enforcement and mutually recognised reporting.
Technical secretariat / independent reviewer	Maintain common definitions and the reconciliation log; coordinate operational and carbon review. Publish methods, maturity states and limitations, with review independence and funding disclosed.

Annual corridor statement and bounded pilots

Publish a yearly statement covering service reliability, total and intensity emissions, Grey Carbon, retained productive value, programme status and proposed / committed / disbursed finance. Show baselines, changes in boundaries, factors and methods, uncertainty, missing data and verification scope. Explain results that improve a ratio while worsening absolute totals. [P]

Run bounded pilots before corridor-wide mandates. Each pilot requires a comparable baseline, activation conditions, a review period, acceptance thresholds, an accountable sponsor and a stop or redesign rule. Combine operational and carbon review so a nominally cleaner option cannot conceal unreliable or unproductive service. [P]

F8. Financing portfolio and whole-life investment decisions

No single instrument finances an entire corridor transition. Match finance to cash flow, maturity, public benefit and risk allocation; availability must be established rather than assumed. Apply the currency-mismatch and institutional-capability tests in Part VI. [P]

Table 37. Finance instruments matched to corridor work packages

Instrument	Suitable application and financing gate
Public and DFI finance	Enabling rail, borders, common-use infrastructure and public-benefit preparation. Establish mandate, procurement, fiscal capacity and delivery accountability; distinguish sovereign allocations from operator revenue.
Project finance	Nodes and services with enforceable contracted cash flows. Test demand, tariff, availability, operating rights, construction / interface risk and debt-service coverage under currency and reliability stress.
Corporate debt and equipment finance	Retrofits, efficient equipment and proven energy improvements. Test operator balance sheet, savings evidence, collateral, useful life and repayment affordability.
Green or sustainability-linked instruments	Eligible asset bundles or credible performance-linked programmes. Specify use of proceeds or material KPIs, baseline, verification and contractual consequences; labels do not verify carbon reduction.
Blended and concessional finance	Justified first-of-kind, preparation or SME constraints. Specify additionality, risk sharing and time-bound support; show how concessionality avoids subsidising an otherwise uneconomic or unaccountable proposal.
Carbon credits, where eligible	Supplementary revenue only after additionality, methodology, permanence where applicable, leakage, verification and market access are demonstrated. Do not treat speculative credits as assured base-case debt service.

Approval record

For each capital proposal, publish the chosen service objective, alternatives considered, whole-life cost and emissions, local capability implications, procurement evidence, financing currencies and residual risks. Record the decision, responsible authority and unresolved conditions. Financial closure is not proof of Productive Yield; track actual service, retained value and carbon performance after commissioning. [P]

Hydrogen readiness and future fuel optionality should be assessed as design options. They are not reasons to incur premature capital expenditure without a feasible supply, demand, safety and lifecycle case. Gas options require explicit methane and upstream lifecycle assumptions; offsets must remain separate from direct operating reductions. [P]

F9. Dated evidence context and supplementary sources

The following context was checked against primary published sources on 6 October 2026. These are dated national or portfolio statements, not measured outcomes of the proposed Durban programmes. Supplementary source identifiers F-S1 to F-S3 are specific to this annex and do not replace the monograph's existing numbered evidence notes.

F-S1. Eskom supply portfolio, financial year ended 31 March 2025

Eskom's September 2025 results presentation reports 216.6 TWh of electricity supplied, with coal accounting for 83%, wind 5%, nuclear 4%, hydro 3%, solar 3%, diesel 1% and other sources below 1%. The reported supply is net of pumping and excludes wheeling. This historical portfolio is not a current national grid mix, an emission factor or the contracted energy mix of a Durban node. [SR; F-S1]

Source: Eskom, Group Annual Results 2025, 30 September 2025, slide 20, electricity supplied by technology and footnote 1.

<https://www.eskom.co.za/wp-content/uploads/2025/09/Eskom-results-presentation-2025.pdf>

F-S2. National road share and rail ambition, 16 March 2026

The President's National Transport Conference address states that approximately 69% of all freight moves by road and sets a target of 250 million tonnes of freight by rail by 2029. These are a government-reported national baseline and a policy target, respectively. Neither is a measured Durban modal share or a demonstrated future rail outcome. [SR; F-S2]

Source: President Cyril Ramaphosa, inaugural National Transport Conference, 16 March 2026; freight-network imbalance and rail-target paragraphs.

<https://www.gov.za/news/speeches/president-cyril-ramaphosa-inaugural-national-transport-conference-16-mar-2026>

F-S3. National Just Energy Transition investment requirement

The November 2022 Presidential Climate Commission remarks describe R1.5 trillion as the financing requirement for the 2023–2027 national Just Energy Transition Investment Plan. This is a historical national investment requirement, not financing already mobilised, a Durban allocation or proof of finance available to an individual project. [SR; F-S3]

Source: The Presidency, remarks on the Just Energy Transition Investment Plan, 4 November 2022 (posted 11 November 2022); five-year financing requirement.

<https://www.thepresidency.gov.za/remarks-president-ramaphosa-presidential-climate-commission-just-energy-transition-investment-plan>

Source scope: the author-supplied Durban report provides the proposed implementation content. Its port-capacity, regional masterplan and macroeconomic-cost figures are not adopted here as current operational baselines. Asset-level embodied shares, node emission factors and project finance availability require their own dated evidence.

NOTES TO MATERIAL EVIDENCE CLAIMS

The notes below retain the manuscript's identified evidence base. Source-reported and historical claims require current route-specific reconciliation before investment use; this editorial rebuild does not certify an independent audit of every underlying source.

1. UNEP describes Avoid-Shift-Improve as a transport-mitigation framework that avoids unnecessary travel, shifts unavoidable demand to more efficient modes and improves the emissions performance of the remaining transport.
2. ISO 14083:2023 establishes a common methodology for quantifying and reporting GHG emissions from passenger and freight transport-chain operations; the GLEC Framework provides aligned logistics-emissions guidance.
3. European Commission: the definitive CBAM regime applies from 1 January 2026 and initially covers cement, iron and steel, aluminium, fertilisers, electricity and hydrogen.
4. African Development Bank, Lobito Integrated Economic Corridor Development Project appraisal, 2026: the source manuscript describes a corridor that links Angola, DRC and Zambia from Lobito to the Copperbelt and is framed as relevant to mining as well as potential agricultural and industrial trade.
5. East Africa Marine Transport / PIDG: M.V. Mpungu provides scheduled RoRo service between Port Bell and Mwanza; PIDG reports capacity up to 21 loaded trucks / 1,000 tonnes and an approximately 18-hour crossing.
6. World Bank/EAC 2015 corridor modelling used historical Lake Victoria water-freight and nodal cost assumptions. These are retained only as historical benchmarks and are not current M.V. Mpungu tariffs.
7. World Bank, Enhancing Export Manufacturing Competitiveness in Lesotho / New Markets Diagnostic for Lesotho's Textile and Apparel Sector, Figure 20, 'Cotton Value Addition in the Export Value Chain by stages': approximately US\$1.4/kg lint, US\$3/kg yarn, US\$5/kg fabric and US\$8-10/kg garments, presented as indicative value added by production stage.
8. Transnet Rail Infrastructure Manager / SANews, 13 May 2026: 11 Train Operating Companies were allocated slots across five strategic corridors; the allocation was expected to add about 24 million tonnes of freight capacity. Operator commencement dates vary and should be treated as implementation reporting.
9. ECOWAS Commission, 3 July 2025: regional resolutions called for accelerated preparation and implementation of a regional cabotage regime in connection with the Praia-Dakar maritime link.
10. World Bank, 12 June 2026: the Douala-Bangui programme reported transport costs as high as US\$270/t, normal journey times of 9-12 days and 38 checkpoints in Cameroon, including 17 involving informal payments.
11. European Commission: maritime transport is subject to EU ETS coverage and FuelEU Maritime requirements; the monograph treats these as market-access and operating-context drivers, not as African regulatory substitutes.
12. Aggreko, From Flare to Value (2026). The publisher's announcement describes four approaches to commercialising flared gas. The manuscript uses this vendor framing as an energy-geography, offtake and modularity analogue. It does not verify a site-level saving or establish a preferred fuel.

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14. World Bank Global Findex, Financial Inclusion in Sub-Saharan Africa: regional analysis identifies mobile-money adoption as a major driver of account ownership and financial inclusion, while noting that cash remains important and inclusion varies substantially by country and population group.
15. SSATP, Embracing Informal Transport: A New Paradigm for Urban Mobility (2025): based on case studies from 14 African cities, the report argues for collaboration, integration and reform of informal public transport rather than simple replacement.
16. African Union Commission, 30 April 2026: African transport and energy ministers endorsed the Pan-African Action Plan for Active Mobility and a Continental Framework on Electric Mobility at the 5th Ordinary Session of the AU Specialized Technical Committee on Transport and Energy.
17. SSATP, Mobility and Accessibility in Urban Areas of Africa / EASI framework: urban mobility policy should Enable, Avoid/Reduce, Shift/Maintain and Improve, including multimodal public transport, walking, cycling and integrated paratransit.
18. African Development Bank, Cross-Border Road Corridors: Expanding Market Access in Africa and Nurturing Continental Integration, 9 November 2023: roads carry about 80% of goods and 90% of passenger traffic; the review reported intra-African trade at about 18% of total goods traded.
19. Ranganathan and Foster, The SADC's Infrastructure: A Regional Perspective, World Bank Policy Research Working Paper 5898, December 2011, section 2 (printed p. 7): historical road freight tariffs of US\$0.05-0.13/t-km across Africa versus US\$0.01-0.04/t-km in much of the developing world. These dated benchmarks are contextual, not present-day quotations.
20. Kenya Ports Authority, 2025 performance release: Mombasa handled 45.45 million tonnes and 2.11 million TEUs in 2025, including 15.88 million tonnes of transit cargo.
21. Port Autonome d'Abidjan, results release dated 2 March 2026: 46.9 million tonnes of net traffic in 2025. Net and gross traffic are distinct measures. [N21]
22. Nigerian Ports Authority, 12 March 2026 release on 2025 operational performance: 129.3 million tonnes total cargo throughput across Nigerian ports in 2025.
23. African Development Bank, 6 August 2026: approved US\$255 million concessional financing and a US\$10 million grant to support Zambia's participation in the Lobito Economic Corridor initiative.
24. World Bank, Increasing Connectivity for Enhanced Food Supply Chain Resilience, 11 April 2024: the Abidjan-Lagos Trade and Transport Facilitation Project (2010-2018) is reported to have reduced truck/merchandise travel and border-crossing times by 47%.
25. World Bank, Central Africa Regional Waterways Project (P175235), Project Appraisal Document, 2023, with 2026 implementation reporting: the project combines waterways, ports, roads, governance and trade facilitation between the Central African Republic and Republic of Congo.

26. UN Trade and Development, Sustainable Smart Port Assessment of Port Louis, Mauritius: stakeholder assessment and roadmap process, 2024-2025, with follow-up Sustainable Smart Ports in Africa work in 2026.
27. World Bank Group and partner institutions, PPP Reference Guide Version 3: commercial structure and PPP design should clarify service objectives, lifecycle responsibilities, risk allocation and performance-linked remuneration rather than treat a contractual label as a preferred model.
28. UN Trade and Development, Review of Maritime Transport 2025, Chapter 2: MSC held about 20% of global liner shipping capacity in TEU terms in April 2025 amid major alliance restructuring.
29. Kenya Ports Authority reports Kisumu throughput of 496,516 tonnes in 2025. Its release gives a 295,516-tonne prior-year baseline, 55.0% growth and a 163,085-tonne increase, which do not reconcile arithmetically. This edition retains the reported 2025 tonnage and suspends the growth claim pending an authoritative reconciliation. [N29]
30. African Development Bank, 6 August 2026: the Zambia Lobito financing approval comprises a US\$255 million concessional loan and US\$10 million grant; the first tranche is under ADF-16, with mobilisation envisaged up to US\$500 million, and includes about 550 km of new railway and a 105 km Mwinilunga-Jimbe road upgrade.
31. World Bank, The WEB of Transport Corridors in South Asia (2018): corridor appraisal should consider wider economic and social outcomes, heterogeneity across places and groups, trade-offs, complementary policies and the distinction between direct transport benefits and wider economic impacts.
32. International Transport Forum/OECD, Incorporating Wider Economic Impacts within Cost-Benefit Appraisal (2016): wider impacts can arise through economic density/productivity, induced investment/land-use change and employment, but require careful treatment within CBA.
33. International Transport Forum/OECD, Broadening Transport Appraisal (2022): appraisal should incorporate wider policy objectives, uncertainty, climate impacts, distribution/accessibility and systematic ex-post evaluation.
34. International Transport Forum/OECD, Guidance for Incorporating Resilience in Cost-Benefit Analyses (2026): resilience can be embedded systematically within appraisal of disruptive events rather than treated as an unpriced afterthought.
35. World Bank, Transport Economic Appraisal Notes: conventional appraisal should retain NPV/BCR/IRR, risk, financial appraisal, distributional analysis and wider impacts as distinct but connected analytical layers; Monte Carlo and real-options methods can support uncertainty analysis where inputs justify them.
36. World Bank, Shrinking Economic Distance (2024): transport prices, time and reliability are shaped by infrastructure, geography, market structure and frictions; reducing economic distance can affect productivity, jobs, incomes, food security and emissions.
37. Roberts, M.; Melecky, M.; Bougna, T.; Xu, Y., World Bank Policy Research Working Paper 8302, Transport Corridors and Their Wider Economic Benefits: A Critical Review of the Literature (2018): reviews evidence on wider corridor effects and highlights the challenge of distinguishing direct transport benefits from wider economic outcomes.
38. UK Department for Transport, Transport Analysis Guidance (TAG), current guidance accessed September 2026: includes dedicated guidance for cost-benefit analysis, wider economic impacts, modelling, uncertainty and evaluation.

39. International Transport Forum/OECD, *Broadening Transport Appraisal* (2022): recommends broader appraisal of accessibility, equity and climate objectives, explicit treatment of uncertainty and systematic ex-post evaluation while retaining CBA as a core analytical tool.
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AUTHOR'S NOTE

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Nursimulu, Rhavy. Re-Architecting African Freight: How Movement Can Build Africa's Productive Economy. Africa Intelligent Corridors 2030 Monograph Series. LOGI-CONSULT, Port Louis, 2026.

This monograph is part of a wider body of work on Africa's economic architecture. It does not prescribe one mode, one fuel, one urban form or one institutional model for a continent of radically different geographies. It proposes a discipline for asking better questions about the physical economy and then requires those questions to be tested with evidence.

Its architecture should not be confused with a prediction that a particular mode, fuel, corridor investment or localisation strategy will always perform best. The architecture specifies how the physical economy should be interrogated and connected; the methodology tests the choices made within it. A road, railway, waterway, port, SEZ, energy system or digital layer earns its place through the function it performs in the complete productive system, not through doctrine alone. [P]

The work is intentionally development-first. It treats decarbonisation as a necessary transformation of African growth, not as a substitute for growth. It therefore places energy access, industrialisation, enterprise, markets, cities, mobility, market power, regulation and productive sovereignty inside the freight question rather than outside it. It also treats metropolitan circulation as an African systems question: technology, mobility, logistics, digital money and commerce should be designed around the social and economic identity of the places they serve.

Intellectual provenance. The propositions in this monograph sit within the author's wider AIC2030 body of work and are distinguished from external evidence through the evidence-status protocol. Concepts developed internally should therefore be cited as authored propositions and tested against independent evidence rather than presented as established external theory.