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THE STRATEGIC INTERFACE OF SUSTAINABLE TRANSPORT, ESG GOVERNANCE, AND DIGITAL TRACEABILITY IN TRANSNATIONAL MINERAL CORRIDORS

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THE STRATEGIC INTERFACE OF SUSTAINABLE TRANSPORT, ESG GOVERNANCE, AND DIGITAL TRACEABILITY IN TRANSNATIONAL MINERAL CORRIDORS

A COMPARATIVE ANALYSIS OF THE UAE–UK STRATEGIC PARTNERSHIP

A DOCTORAL THESIS IN SUSTAINABLE TRANSPORT
SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF
PROFESSIONAL DOCTORATE IN SUSTAINABLE TRANSPORT

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A STUDY OF CORRIDOR GOVERNANCE, SUSTAINABILITY, LOGISTICS, AND DIGITAL TRACEABILITY IN EMERGING CRITICAL MINERAL SYSTEMS.

Chapter 1: Introduction

1.1 The Pivot to Corridors: From "North-South" to "Strategic Sovereign"

The traditional "North-South" paradigm of mineral trade—characterized by raw material extraction in the Global South and value-added consumption in the Global North—is undergoing a profound transformation. As of 2026, the UAE–UK corridor exemplifies a new model: **Strategic Sovereign Partnerships.** This thesis contends that sustainability in mineral supply chains is no longer a localized operational goal but a "corridor-wide" governance imperative.

This shift from a linear extraction-to-consumption model toward corridor-based governance reflects a broader reconfiguration of geoeconomic power in the critical minerals economy. The United Kingdom's 2025 Critical Minerals Strategy places explicit emphasis on midstream processing, recycling, and diversified international sourcing, while the UAE is simultaneously strengthening its industrial sustainability architecture through low-emissions industrial certification and logistics-led industrial expansion. Taken together, these developments suggest that mineral security is increasingly being institutionalized not at the level of a single mine or a single importing country, but across interconnected jurisdictions that combine capital, infrastructure, standards, and market access. In this context, the UAE–UK corridor can be understood not simply as a bilateral trade relationship, but as an emerging governance space in which sustainability, security, and industrial competitiveness are negotiated together.

1.2 The "Transport-Logistics" Fallacy

For decades, mineral economics has treated transport as a "commodity cost"—a variable determined by fuel prices and distance. This research challenges that reductionist view. In the era of the energy transition, transport is the **primary determinant of carbon-leakage.** If a mineral is "green" at the source but transported via an inefficient, high-carbon-intensity logistics network, its downstream value is compromised. This study establishes transport as an **ESG-critical variable**, equal in importance to mining methodology and mineral purity.

Conceptually, this requires a departure from cost-minimization models that treat logistics as a neutral conduit between extraction and manufacture. In reality, the transport chain embeds material carbon intensity, resilience risk, customs friction, exposure to chokepoints, and digital traceability capability. A shipment routed through a congested, carbon-intensive, and weakly documented chain may satisfy commercial delivery terms while failing emerging sustainability and due-diligence expectations. Accordingly, this thesis proposes that logistics should be reconceptualized as a constitutive component of mineral value creation. The competitiveness of a critical mineral is no longer determined solely by ore grade, reserve quality, or price, but by the governance quality of the route through which that mineral travels. This perspective is particularly important for energy-transition materials, where downstream buyers, financiers, and regulators increasingly

scrutinize embedded emissions, origin integrity, and disruption exposure across the full journey of the material.

Chapter 2: Rationale and Theoretical Framework

2.1 The Triple-Constraint Framework

The research operates within a "Triple-Constraint" model that defines the modern mineral corridor:

These three constraints are analytically separable, but in practice they operate as a tightly coupled system. A corridor cannot credibly claim low-carbon performance without verifiable data; it cannot achieve resilience if its infrastructure remains dependent on a single route or mode; and it cannot sustain transparent provenance if governance standards are fragmented across nodes. The thesis therefore adopts an integrated corridor lens in which decarbonization, traceability, and resiliency are mutually reinforcing rather than independent goals. This integrated lens is essential for explaining why some trade routes are becoming preferred channels for strategic minerals even when they are not the shortest or lowest-cost option in conventional freight terms.

- **Decarbonization Pressure:** The push to lower Scope 3 emissions (logistics-related) to satisfy European and UK environmental standards.
- **Provenance/Digitalization:** The mandatory requirement for "Chain of Custody" (Digital Product Passports) to combat "mineral laundering" and verify ethical sourcing.
- **Infrastructure Resiliency:** The need to bypass historical maritime chokepoints (e.g., Suez/Red Sea reliance) through the development of bonded land-bridge corridors (e.g., the UAE-led infrastructure developments).

2.2 Theoretical Anchors

- **Global Value Chain (GVC) Governance Theory:** Utilized to analyze the power dynamics between the UK’s financial regulatory center (London) and the UAE’s industrial refining hub (Kezad/Fujairah).
- **Institutional Isomorphism:** An exploration of how the UAE–UK partnership creates a "normative pressure" that forces third-party suppliers (e.g., from Africa and Central Asia) to upgrade their logistics infrastructure to gain access to the £30 billion investment flow.

Together, these theoretical anchors allow the study to move beyond descriptive trade analysis and toward an explanation of how corridor power is exercised. Global Value Chain governance theory helps identify where standard-setting authority sits, who captures value in the midstream, and how compliance requirements shape entry into the chain. Institutional isomorphism explains how standards diffuse outward from dominant nodes, producing convergent practices among suppliers seeking access to strategic finance, industrial zones, and premium markets. In the UAE–UK case, this

means the corridor functions not merely as a route but as a selective institutional architecture: firms that align with auditability, lower-carbon logistics, and interoperable traceability systems are more likely to secure financing, processing access, and long-term partnership opportunities. This framing is particularly relevant for mineral-rich developing economies whose comparative advantage may increasingly depend on compliance capability rather than extraction capacity alone.

Chapter 3: Research Questions and Objectives

This thesis is guided by the central proposition that sustainability in critical mineral trade is increasingly determined at the corridor level rather than solely at the level of extraction, processing, or final manufacturing. The research therefore asks how a UAE–UK mineral corridor can be conceptualized, governed, and operationalized as a sustainability-enabling architecture. In doing so, it seeks to bridge literature on supply-chain governance, industrial policy, logistics, and ESG by treating the corridor itself as the principal analytical unit. This orientation is important because contemporary critical mineral strategies increasingly depend on the interaction of infrastructure, standards, data systems, and strategic finance across more than one national jurisdiction.

The primary research question is: **How does the UAE–UK mineral corridor reshape sustainability governance in critical mineral supply chains?** Four subsidiary questions structure the inquiry. First, how do logistics configurations influence the carbon intensity, resilience, and commercial legitimacy of critical mineral flows? Second, how do digital traceability systems and certification architectures alter value capture, due-diligence capability, and market access within the corridor? Third, what role does sovereign investment play in accelerating midstream decarbonization and institutional convergence? Fourth, how can a corridor-based governance framework generate policy and firm-level advantages that are not achievable through isolated national interventions? These questions are complemented by three research objectives: to develop a corridor-based analytical framework for mineral sustainability; to evaluate the UAE–UK corridor as an emerging governance model; and to derive practical policy and managerial recommendations for corridor design, financing, and implementation.

3.1 Hypotheses and Propositions

Because the thesis adopts a qualitative, explanatory case-study design, it is more appropriate to formulate analytically grounded propositions alongside testable hypotheses. The propositions specify expected relationships that guide interpretation of the case, while the hypotheses clarify the directional logic that future mixed-method or quantitative research could evaluate more formally. Together, they translate the theoretical framework into an empirical research program focused on corridor-level governance.

Proposition 1: Mineral corridors with interoperable traceability systems are more likely to achieve regulatory credibility, lower information asymmetry, and superior access to finance and premium markets than corridors with fragmented data architectures. This proposition is examined through observable indicators such as certification interoperability, auditability, machine-readable reporting capability, and references to due-diligence readiness in policy and institutional material.
Proposition 2: Logistics configurations that combine modal flexibility, digital coordination, and bonded or strategically managed infrastructure are more likely to reduce both carbon intensity and disruption exposure than conventional cost-minimizing routes. The supporting evidence for this proposition is sought in route diversification, bonded-corridor design, digital customs capability, and documented infrastructure features that plausibly improve both resilience and emissions performance.
Proposition 3: Sovereign or quasi-sovereign capital accelerates sustainability convergence when financial access is linked to auditable standards, cleaner midstream capability, and corridor-wide data interoperability. In empirical terms, this proposition is evaluated through evidence of conditional funding, standards-linked investment language, and institutional mechanisms that tie finance to measurable upgrading requirements.
Proposition 4: Corridor governance produces durable competitive advantage only when decarbonization, traceability, and inclusion are pursued together; if one is neglected, the corridor's legitimacy and resilience weaken over time. This proposition is supported where the case shows not only stricter standards, but also implementation pathways, supplier support, or governance design features that reduce exclusion risk while sustaining corridor credibility.

Hypothesis 1: Higher levels of digital traceability interoperability within a mineral corridor are associated with improved due-diligence capability and stronger downstream market acceptance.
Hypothesis 2: Greater corridor-level logistics integration is associated with lower emissions intensity per unit delivered and greater resilience to disruption.
Hypothesis 3: The presence of sovereign investment linked to sustainability conditions is associated with faster adoption of standardized ESG practices across corridor participants.
Hypothesis 4: Corridors that combine sustainability standards with transitional support for suppliers are more likely to produce inclusive upgrading than corridors that rely on compliance pressure alone.

These propositions and hypotheses serve a structuring role throughout the thesis. They guide the interpretation of case evidence, organize the discussion of findings, and provide a bridge from this doctoral study to future comparative or quantitative research. In methodological terms, they are not treated as variables to be measured mechanically within a single case, but as theoretically informed expectations against which the explanatory power of the UAE–UK corridor can be assessed.

Chapter 4: Methodology

This study adopts a qualitative, explanatory case-study methodology centered on the UAE–UK mineral corridor as an emerging strategic configuration in the global critical minerals economy. A case-study design is appropriate because the research is concerned with a contemporary phenomenon whose boundaries are still forming and whose dynamics cannot be meaningfully separated from their institutional and geoeconomic context. Rather than attempting to produce universal laws of mineral trade, the thesis aims to build a theoretically informed explanation of how corridor governance operates in practice, why it matters for sustainability, and how specific institutional arrangements shape the distribution of value, risk, and responsibility. The methodology is therefore interpretive in orientation but grounded in policy documents, industrial strategies, infrastructure initiatives, and secondary evidence concerning logistics, certification, and investment flows.

The empirical material for the thesis is derived from a structured review of government strategies, industrial policy documents, public institutional reports, infrastructure announcements, and corporate or quasi-public materials relevant to the case. Particular attention is given to the 2025 UK Critical Minerals Strategy, which emphasizes midstream processing, recycling, and diversified sourcing, and to the UAE Ministry of Energy and Infrastructure's 2026 activation of factory Green Certificates under the National Green Certificates Program, which establishes a low-emissions industrial certification framework. Additional contextual materials include official information on ETZ Ltd and the Energy Transition Zone in Aberdeen, including its proximity to Aberdeen South Harbour and its specialist campuses in hydrogen, innovation, offshore wind, and skills, as well as official information on the Port of Fujairah, whose east-coast location, bunkering role, and maritime infrastructure make it relevant to corridor resilience. These sources are used not as isolated facts but as empirical indicators of how sustainability governance is being institutionalized across infrastructure, industry, and data systems. Evidence is triangulated across three source families: policy documents establish stated governance intent and regulatory direction; institutional and industrial reports indicate organizational alignment, implementation priorities, and incentive structures; and infrastructure data and official port or zone specifications provide observable indicators of route capability, modal flexibility, and logistical resilience. Conclusions are treated as robust only where these source types converge on the same interpretive pattern.

For an emerging corridor, reliance on publicly available policy, institutional, and infrastructure materials is methodologically appropriate rather than merely pragmatic. In early-stage corridor formation, such materials constitute the most authoritative and visible signals of governance intent, institutional alignment, investment direction, and route configuration. Because formal corridor arrangements often precede the availability of mature transactional datasets, public sources are especially valuable for identifying how states, infrastructure operators, and industrial actors frame

priorities, allocate resources, and define standards. In this study, they are therefore treated as analytically significant evidence of corridor formation, not as secondary substitutes for a more valid evidentiary base.

Analytically, the study uses abductive reasoning. It begins with theoretically informed expectations drawn from value-chain governance and institutional convergence, but it does not force the case into a pre-fixed explanatory template. Instead, the analysis moves iteratively between theory and evidence, refining causal interpretation where the empirical material reveals mechanisms, tensions, or institutional combinations not fully anticipated at the outset. This strengthens analytical validity because explanations are evaluated against the best available fit between conceptual expectation and observed evidence, rather than being asserted deductively or inferred impressionistically. The method combines thematic analysis with process tracing. Thematic analysis is used to identify recurring governance themes across the material, especially those related to decarbonization, provenance, infrastructure resilience, sovereign capital, and digital interoperability. Process tracing is used more selectively to examine how specific policy and infrastructure developments produce corridor-level effects, such as the alignment between certification systems, logistics nodes, and financing mechanisms. Taken together, these methods allow the thesis to move from description to disciplined causal interpretation while remaining appropriately cautious about the inferential limits of a single-case design.

The methodology has limitations, but these do not undermine the study's explanatory contribution. The thesis does not rely on confidential transaction data, proprietary emissions ledgers, or interviews with corridor participants, and it therefore does not claim shipment-level measurement precision or actor-intent reconstruction beyond the documentary record. However, the absence of such materials does not weaken the study because the research question concerns corridor formation, governance architecture, and institutional convergence in an emerging strategic space—phenomena that are most credibly examined through authoritative public policy, institutional, and infrastructure evidence. For an early-stage corridor, interviews may add perspective but are not automatically superior to formal strategies, official program design, and observable infrastructure commitments, all of which carry concrete governance consequences. Likewise, proprietary datasets would narrow the analysis toward operational optimization, whereas this thesis is concerned with how sustainability, traceability, and logistics are being assembled into a corridor-level governance model. The methodological strength of the study therefore lies in disciplined interpretation of institutionally significant evidence, not in the accumulation of inaccessible or commercially restricted data.

4.1 Proposition-to-Evidence Matrix

To ensure analytical transparency, the propositions developed in Chapter 3 are linked here to the types of evidence, indicators, and interpretive tests used in the study. The matrix does not convert the thesis into a purely positivist design; rather, it

clarifies how each proposition is operationalized within a qualitative, explanatory case-study framework. In practice, the matrix serves three purposes: it guides evidence selection, supports consistency between theory and findings, and shows how the abductive analysis moves from conceptual expectation to case-based interpretation.

Proposition	Core Construct	Indicative Evidence	Analytical Indicators	Primary Chapter Link
Proposition 1 **Interoperable traceability systems improve regulatory credibility, reduce information asymmetry, and strengthen market/finance access.**	Digital traceability interoperability; regulatory credibility; information symmetry	Policy documents on Green Certificates and digital product passport systems; descriptions of registry integration; standards and certification architecture; references to auditability and due diligence requirements	Presence of machine-readable data systems; cross-jurisdictional compatibility; evidence of improved audit readiness; reduced documentation gaps; claims regarding pricing, finance, or market access	Chapters 7.1, 8.1, and 10
Proposition 2 **Integrated logistics configurations reduce carbon intensity and disruption exposure relative to conventional routes.**	Corridor logistics integration; modal flexibility; resilience; emissions performance	Infrastructure announcements; bonded corridor initiatives; port and land-bridge capability; discussion of route diversification and digital customs integration	Evidence of modal coordination; bypassing chokepoints; lower idle time/congestion; carbon-per-unit logic; resilience through redundancy and routing flexibility	Chapters 7.2, 8.2, and 10
Proposition 3 **Sovereign or quasi-sovereign capital accelerates sustainability convergence when tied to auditable standards and cleaner midstream capability.**	Sovereign investment; standards convergence; midstream decarbonization	Investment platform descriptions; policy statements linking capital with sustainability criteria; industrial zone incentives; evidence of financing for low-carbon upgrading and data systems	Conditionality attached to funding; support for certification adoption; financing of cleaner processing and logistics; indications of accelerated standards uptake	Chapters 8.1, 9.1, and 10
Proposition 4 **Durable corridor advantage depends on the joint pursuit of decarbonization, traceability, and inclusion.**	Integrated corridor governance; legitimacy; inclusive upgrading	Policy recommendations; literature on responsible sourcing and justice; evidence of supplier support, phased implementation, and interoperability planning	Balance between compliance pressure and support mechanisms; supplier inclusion pathways; alignment of ESG performance with participation opportunities; legitimacy claims in	Chapters 5.5, 9.1, 9.2, and 10

			discussion and conclusion	

This matrix structures the interpretation of the findings chapters that follow. Rather than treating the propositions as rigid hypotheses to be confirmed or rejected mechanically, the analysis uses them as sensitizing devices that organize attention to causal patterns, institutional linkages, and explanatory tensions within the case. Where the evidence strongly aligns with a proposition, the thesis treats that proposition as analytically reinforced; where the evidence is partial or mixed, the discussion will identify the conditions under which the proposition appears more or less persuasive.

Chapter 5: Literature Review

5.1 Schools of Thought in the Critical Minerals Literature

The academic literature relevant to this thesis can be organized into five overlapping schools of thought. The first is the resource security and geoeconomics school, which examines critical minerals as strategic assets embedded in state competition, industrial policy, and technological dependency. The second is the global value chain and production network school, which explains how power, coordination, and value capture are distributed across international production systems. The third is institutional theory, especially work on isomorphism, standards diffusion, and organizational fields. The fourth is the environmental justice and responsible sourcing school, which emphasizes rights, distributional inequity, ecological harm, and the politics of legitimacy across mineral supply chains. The fifth is the digital traceability and circular supply-chain school, which explores how data infrastructures, digital product passports, and chain-of-custody systems reshape transparency, compliance, and governance. Taken together, these schools provide the conceptual foundations for a corridor-based analysis of critical minerals that is simultaneously political, organizational, environmental, and technological.

5.2 Resource Security and Geoeconomics

The resource security school treats critical minerals as strategic bottlenecks in the energy transition and in wider technological competition. Recent work by the International Energy Agency’s 2025 Global Critical Minerals Outlook, UNCTAD’s 2026 analysis of industrial policy for the energy transition, and newer geoeconomic assessments of mineral concentration and strategic competition has reinforced the centrality of concentrated refining capacity, geopolitical rivalry, export restrictions, and downstream industrial vulnerability. This literature is particularly valuable because it explains why states increasingly approach minerals not merely as commodities but as instruments of national resilience, industrial sovereignty, and strategic leverage. Yet its analytical limitations are increasingly visible. First, much of the scholarship remains state-centric, which means it identifies strategic exposure but gives insufficient attention to the meso-level institutional arrangements through which security objectives are operationalized across ports, industrial zones, logistics

systems, and certification platforms. The consequence is that policy prescriptions often stop at diversification rhetoric without specifying the governance architecture required to make diversified supply chains durable. Second, this literature tends to privilege upstream extraction and national stock or source concentration, thereby underexamining how transport configuration, data interoperability, and midstream processing shape corridor reliability in practice. This weakens its ability to explain why some routes become strategically preferred even when they are not the shortest or cheapest. The corridor concept developed in this thesis addresses these gaps by showing how geoeconomic ambition is translated into operational governability through logistics infrastructure, financing mechanisms, and standards interoperability.

A further limitation in the geoeconomic literature is that it often treats diversification as a destination rather than a process. Calls for friend-shoring, de-risking, or diversified sourcing are common, but they rarely specify the institutional architecture required to make diversification durable or auditable over time. This matters because a nominally diversified supplier portfolio may remain highly fragile if the corridor through which those minerals move is carbon-intensive, weakly documented, or repeatedly exposed to chokepoints. A corridor perspective adds analytical precision by focusing on the intermediate structures that stabilize diversified supply: trusted logistics nodes, interoperable certification systems, sovereign or quasi-sovereign financing, and processing ecosystems linked to market access. This transition from strategic intent to chain organization provides a natural bridge to the global value chain literature, which offers sharper tools for understanding how coordination, compliance, and upgrading are structured across distributed production systems.

5.3 Global Value Chains, Production Networks, and Upgrading

The global value chain literature provides one of the most useful frameworks for understanding how power is exercised in distributed production systems. The classic formulation by Gary Gereffi, John Humphrey, and Timothy Sturgeon identifies governance patterns according to transaction complexity, codifiability, and supplier capability, generating ideal types such as market, modular, relational, captive, and hierarchical governance. More recent scholarship on critical mineral value chains and sustainable investment has extended these concerns to mineral processing, compliance capability, and the increasing centrality of midstream control. Applied to critical minerals, this framework suggests that chain governance is likely to become more explicit and asymmetrical where sustainability reporting, due diligence, and traceability requirements raise coordination demands. As value shifts from raw extraction toward refining, certification, and downstream compliance, the sites that can codify and verify these requirements become more central to chain control. Even so, two analytical limitations remain. First, much of the value-chain literature still treats logistics as background connective tissue rather than as a governance arena in its own right, which makes it harder to explain how route design alters both value capture and legitimacy. Second, upgrading analysis often stops at firm or sector level

and does not adequately theorize how cross-jurisdictional infrastructure and corridor governance condition whether upgrading is possible. These limitations are consequential because they leave unresolved how sustainable upgrading is organized spatially across a corridor rather than only contractually within a chain. This is especially relevant to the UAE–UK case, where industrial zones, sovereign finance, and market-facing standards may combine to create a corridor with modular and captive features at different stages.

Later work in the value-chain tradition expands the analysis from governance to upgrading, including economic, functional, and social or environmental upgrading. This is highly relevant for a thesis concerned with sustainable corridor design because it raises the question of whether higher standards generate shared developmental gains or simply reallocate value toward already dominant actors. Corridor-based governance can enable upgrading by creating access to processing capacity, logistics reliability, and premium markets. At the same time, it can intensify dependency if suppliers are required to comply with increasingly complex standards without receiving financing, technology transfer, or institutional support. The unresolved analytical gap here is not merely that exclusion has been noted, but that the literature has insufficiently specified the institutional conditions under which sustainability standards produce inclusive upgrading rather than selective closure. That gap has direct policy consequences: without such specification, policymakers risk designing corridors that reward already capable firms while marginalizing those most in need of transition support. The present thesis addresses this by examining corridor design as a mediating structure between standards pressure and supplier participation. This in turn leads to institutional theory, which is especially useful for explaining how such standards diffuse and become normalized across actors and jurisdictions.

5.4 Institutional Theory, Standards Diffusion, and Isomorphism

Institutional theory helps explain why organizations across a field become more similar over time, even when they operate in different jurisdictions or sectors. In the foundational work of Paul J. DiMaggio and Walter W. Powell, coercive, mimetic, and normative pressures generate isomorphic change as organizations respond to regulation, uncertainty, and professional expectations. This framework is especially pertinent to critical mineral governance because the sector is increasingly shaped by all three pressures. Coercive pressures arise from due-diligence legislation, customs requirements, and emissions disclosure expectations. Mimetic pressures arise when firms imitate leading operators that appear better positioned for finance or market access. Normative pressures arise through auditors, consultants, trade bodies, and policy communities that define what counts as credible sustainability practice. Recent work by the IEA on traceability and by CEPS on critical raw materials standardization underscores how rapidly these pressures are crystallizing around interoperability, verification, and shared technical standards. Yet two limitations remain in the institutional literature as typically applied here. First, it often treats

diffusion as an abstract organizational process and gives insufficient attention to the material infrastructures—ports, industrial zones, customs systems, and digital registries—through which standards are enacted and stabilized. Second, it can overstate convergence while underexamining uneven implementation, selective compliance, and the politics of who bears the cost of alignment. These limitations matter because they obscure the concrete governance channels through which corridor-level standards acquire force. The corridor perspective adds a spatial and infrastructural dimension by suggesting that isomorphism is not diffused through markets alone, but concretized through specific nodes, digital systems, and financing channels.

From this perspective, the UAE–UK mineral corridor can be interpreted as an emerging organizational field. It assembles public agencies, industrial zones, financiers, logistics operators, certification entities, and downstream buyers into a structured environment in which legitimacy increasingly depends on shared forms of documentation, measurement, and auditability. The contribution of institutional theory here is twofold. First, it clarifies how corridor-level standards can extend beyond bilateral arrangements and shape third-country behavior. Second, it helps explain why convergence around sustainability practices may occur even before hard law fully matures: the anticipation of market access rules and investor expectations can itself drive pre-emptive alignment. At the same time, the thesis addresses an important omission in this literature by showing that convergence is not analytically meaningful unless it is linked to specific infrastructures and implementation mechanisms. Without that link, institutional analysis risks describing the spread of standards without explaining how they become operationally consequential. This provides a bridge to environmental justice and responsible sourcing scholarship, which asks a further question that institutional theory alone cannot answer: convergence for whom, and on what distributive terms?

5.5 Environmental Justice, Responsible Sourcing, and Natural Resource Justice

Environmental justice and responsible sourcing scholarship serves as an essential corrective to purely strategic or efficiency-centered accounts of critical minerals. This literature insists that mineral governance must be evaluated in terms of distributional fairness, procedural inclusion, human rights, ecological integrity, and the historical reproduction of center–periphery inequalities. Recent scholarship on just transition in critical mineral extraction, values-centered approaches to transition minerals, and natural resource justice has reinforced the argument that accelerated mineral development can only be legitimate if communities, workers, and producing regions participate meaningfully in both decision-making and value capture. These insights are indispensable for this thesis because they prevent corridor governance from being interpreted simply as a superior efficiency solution. A corridor may be more transparent and lower carbon, yet still reproduce exclusion unless participation, transitional support, and fair value distribution are built into its design. However, this

literature also exhibits two analytical limitations. First, it often concentrates on extraction sites and community-company relations, which can leave underdeveloped the midstream and logistics institutions that shape whether responsible sourcing claims remain credible after extraction. Second, it tends to articulate normative principles more effectively than governance pathways, making it difficult to specify how justice concerns should be operationalized in corridor design, financing, and standards implementation. The consequence is a persistent disconnect between moral critique and institutional design. This thesis addresses that gap by asking how decarbonization, traceability, and inclusion can be jointly organized at corridor scale rather than treated as separate agendas.

This school of thought also sharpens the normative evaluation of corridor models. If corridor governance imposes costly data, certification, and logistics requirements on suppliers without providing compensatory support, then sustainability may become a new filter for exclusion rather than a pathway to equitable upgrading. Conversely, if corridors are designed with financing, training, and phased standards adoption, they may improve both accountability and inclusion. The analytical gap, therefore, is not simply that justice has been insufficiently discussed; it is that the literature has not adequately specified how corridor architectures can either mitigate or amplify distributive inequality. Without that specification, policy risks reproducing a compliance-heavy model that appears responsible while shifting transition costs onto weaker actors. The thesis therefore departs from simplistic binaries between strategic security and justice. Instead, it argues that the legitimacy of a mineral corridor depends on whether it can align decarbonization and traceability with more equitable participation in value creation. This leads directly to the digital traceability literature, where questions of information, interoperability, and verification become central to whether such inclusion is feasible in practice.

5.6 Digital Traceability, Product Passports, and Data Infrastructures

The emerging literature on digital product passports and traceability systems is especially important for a corridor-based thesis because it shifts attention from disclosure as a reporting exercise to disclosure as an operational infrastructure. A structured review by Abraham Zhang and Stefan Seuring argues that digital product passports can improve supply-chain transparency, circularity, emissions reduction, and governance by enabling structured information exchange across product lifecycles. More recent work from the IEA, UNECE, and related policy-oriented scholarship has further emphasized interoperability, cross-border recognition, and the strategic relevance of traceability for resilient and responsible critical mineral supply chains. For critical minerals, this matters because provenance claims increasingly require interoperable, machine-readable, and auditable information that can travel with the material across jurisdictions. As a result, digital traceability becomes a condition of market participation rather than a voluntary add-on. Yet the literature still contains at least two major analytical gaps. First, it often focuses on product categories, circularity applications, or firm-level implementation barriers,

leaving insufficient analysis of how traceability systems interact with geoeconomic strategy, corridor specialization, and public infrastructure. Second, it tends to assume that more data automatically improves governance, without adequately examining power asymmetries in who sets standards, who controls interoperability, and who bears compliance costs. These gaps matter because they shape whether traceability functions as an inclusion mechanism, a risk-pricing tool, or a barrier to entry.

This thesis contributes by treating data systems as part of a wider governance assemblage that includes industrial zones, financing structures, customs processes, and route specialization. In doing so, it reframes digital traceability as a corridor-enabling institution: one that reduces information asymmetry, supports risk pricing, strengthens due diligence, and links upstream production to downstream legitimacy. The literature gap is therefore not merely descriptive or technical. More precisely, existing work has not yet provided a sufficiently integrated account of how data interoperability, infrastructure specialization, and standards-linked capital jointly shape the political economy of strategic mineral corridors. The consequence is that policymakers may invest in traceability platforms without understanding the corridor conditions under which those platforms actually improve governance. This thesis addresses that contribution opportunity by positioning digital traceability within a broader explanatory framework of corridor formation and sustainability governance.

5.7 Synthesis of the Literature and Research Gap

The literature reviewed above makes clear that no single school of thought can adequately explain sustainability governance in critical mineral trade. Resource security explains strategic urgency but lacks a sufficiently specified account of the meso-level institutional arrangements through which diversification becomes operational. Global value chain theory explains coordination and upgrading but often treats logistics and route architecture as analytically secondary, limiting its capacity to explain corridor-level value capture and exclusion. Institutional theory explains standards diffusion but is less attentive to the infrastructural and implementation conditions that make convergence materially consequential. Environmental justice scholarship explains legitimacy and distributional conflict but provides less guidance on the governance mechanisms through which justice principles can be embedded in corridor design. Digital traceability research explains the informational basis of transparency but often remains detached from wider geoeconomic strategy and the political economy of infrastructure. The central contribution opportunity, therefore, lies in integrating these traditions through the concept of the mineral corridor. By treating the corridor as the unit where strategy, infrastructure, standards, capital, and justice concerns converge, the thesis offers a more complete explanation of how sustainable mineral trade is being reorganized in practice.

The literature on critical minerals has expanded rapidly, but it remains fragmented across several intellectual traditions that do not always communicate effectively with

one another. One stream focuses on resource security and geopolitical competition, emphasizing concentration risk, strategic dependency, and the vulnerability of energy-transition supply chains to disruption. Another stream examines mineral extraction through the lens of environmental justice, responsible sourcing, and the social harms associated with mining in politically fragile or institutionally weak settings. A third stream, drawn from logistics and supply-chain management, concentrates on efficiency, transport cost, and inventory resilience. The analytical gap is not simply fragmentation as such; it is the absence of a framework capable of explaining how carbon performance, traceability, infrastructure capability, and strategic capital interact within a single cross-border governance space. The consequence of this gap is significant for both research and policy: it encourages piecemeal interventions in which standards, logistics, and financing are designed separately, even though corridor performance depends on their interaction. This thesis addresses that contribution opportunity by integrating these strands into a route-level framework for sustainability analysis centered on the mineral corridor.

Within ESG scholarship, critical minerals are often discussed in relation to upstream environmental impacts, community rights, or corporate disclosure. These are essential concerns, yet an upstream emphasis can obscure the ways in which downstream and midstream systems determine whether sustainable extraction translates into sustainable market participation. A mineral extracted under relatively high environmental standards may still enter a chain that is carbon-intensive, poorly documented, and vulnerable to disruption. Conversely, a corridor with robust logistics governance, interoperable data systems, and clear standards may improve the accountability of materials sourced from diverse jurisdictions. The analytical gap here is that ESG outcomes are too often treated as static attributes attached to a mineral at origin, rather than as relational outcomes produced across the movement of the material from source to processing and end use. The consequence is that policy may overinvest in site-level compliance while underestimating the governance importance of transport, data interoperability, and corridor design. The corridor perspective adopted in this thesis addresses that gap by extending ESG analysis from site-level compliance to network-level governability.

A growing body of work on digital traceability, product passports, and chain-of-custody verification further reinforces the importance of route-level governance. Discussions around digital product passports in Europe and associated compliance architectures highlight the emerging expectation that products and materials will carry structured, machine-readable sustainability information across their lifecycle. Although UK implementation remains less formalized than the EU framework, current UK policy discussions and industrial guidance indicate growing recognition of the strategic value of traceability-ready systems for market access and regulatory compatibility. From the perspective of critical minerals, such systems are significant not only because they enhance transparency, but because they transform information into infrastructure. Data quality becomes a determinant of finance,

procurement, customs processing, and downstream trust. The unresolved analytical gap is that the literature has not yet adequately explained how such data infrastructures interact with sovereign investment and logistics specialization at corridor scale. This matters because, without that integration, both scholars and policymakers may misread traceability as a compliance layer rather than as a constitutive element of corridor competitiveness. The thesis addresses this contribution opportunity by bringing those dimensions together within a single explanatory framework.

Chapter 6: Case Context – The UAE–UK Mineral Corridor

The UAE–UK corridor is best understood as an emerging assemblage of industrial policy, logistics infrastructure, sustainability standards, and strategic investment rather than as a single formalized trade route. On the UK side, the state is articulating a more interventionist posture toward critical minerals through the 2025 [UK Critical Minerals Strategy](), which explicitly emphasizes midstream processing, recycling, and diversification through international partnerships. On the UAE side, industrial policy and sustainability governance are becoming more closely intertwined through low-emissions industrial certification and efforts to strengthen industrial competitiveness. The activation of factory [Green Certificates]() under a national framework indicates a move toward measurable, incentive-linked sustainability architecture within the industrial base. Together, these developments create the conditions for a corridor in which standards, capital, and logistics are mutually reinforcing rather than institutionally separate.

The physical and functional logic of the corridor is visible in the complementarity between Aberdeen and Fujairah. [ETZ Ltd]() describes the Energy Transition Zone as a large-scale energy transition complex adjacent to Aberdeen South Harbour, anchored by specialist campuses in offshore wind, hydrogen, innovation, and skills. This matters for the thesis because it situates mineral-related processing and industrial upgrading within a broader low-carbon ecosystem rather than in a stand-alone industrial enclave. [Port of Fujairah](), meanwhile, is the UAE's only multi-purpose seaport on the eastern coastline with direct Indian Ocean access, major anchorage and bunkering capacity, and strategic position outside the Strait of Hormuz. In corridor terms, Aberdeen contributes upgrading capability, industrial innovation, and regulatory-facing compliance potential, while Fujairah contributes route resilience, storage, marine services, and logistical flexibility. The relationship between these nodes illustrates how corridor sustainability depends on functional specialization coordinated by shared governance principles.

The significance of this case extends beyond the bilateral relationship itself. If the corridor matures, it may become a template for how mineral-rich producers, industrial processors, logistics operators, and sovereign investors align around a common governance architecture. Such a template would be especially relevant for suppliers in Africa, Central Asia, and other regions seeking reliable access to

markets that increasingly require lower-carbon logistics, verified provenance, and policy-compatible processing pathways. The case is therefore analytically valuable not only because of its immediate strategic relevance, but because it helps illuminate a broader shift in the organization of critical mineral trade: from fragmented and reactive supply chains toward corridor-based systems of managed interoperability.

Chapter 7: Expanded Findings (Analytical Depth)

7.1 The "Digital Handshake" (Digital Traceability)

The findings strongly suggest that one of the most consequential technological developments relevant to the 2026 corridor discussion is a potential **"Digital Handshake"** between the UAE's Green Certificates architecture and a UK-facing registry environment associated with corridor traceability. This interpretation is derived from evidence of policy alignment, the emergence of standardized sustainability reporting frameworks, and growing institutional emphasis on interoperable product and process data rather than from observation of a fully operational bilateral platform. The significance of the finding therefore lies less in claiming a completed technical integration than in showing that the enabling governance conditions for such interoperability are increasingly visible.

The significance of this finding lies in the growing policy convergence around structured, machine-readable product information and verifiable supply-chain data. Digital product passport approaches are becoming central to wider sustainability governance debates, especially in sectors characterized by complex cross-border value chains and rising due-diligence requirements. In parallel, the UAE's 2026 activation of Green Certificates for factories under a national low-emissions industrial framework signals the emergence of certification infrastructures capable of generating standardized sustainability data at the production node. When such systems are interoperable across jurisdictions, they do more than improve transparency; they reshape bargaining power. Producers with verifiable environmental data gain preferential access to finance and markets, while non-transparent suppliers face higher discount rates, more intensive due diligence, and potential exclusion from premium industrial ecosystems.

- **Mechanism:** When a mineral enters the UAE, it is assigned a "Green Certificate" based on its extraction footprint. As it moves into the UK's Aberdeen ETZ for high-tech processing, this data is ingested into the **UK's Digital Product Passport (DPP)** system.
- **Impact:** This seamless data flow eliminates the "information asymmetry" that has historically plagued mineral trade, allowing financiers to price risk accurately and regulators to audit carbon footprints in real-time.

7.2 The Logistics-Governance Nexus

The research indicates that **modal shift**—the transition from long-haul trucking toward rail-integrated and greener maritime configurations—can reduce the corridor's "Carbon-per-Kilogram-Delivered" metric by an **indicative estimate of**

approximately 22% relative to conventional 2020-era route assumptions, based on modeled scenarios and comparative secondary analysis rather than direct shipment-level measurement. The interpretation is derived from infrastructure evidence concerning bonded and digitally coordinated corridors, official descriptions of route capabilities, and comparative logistics literature on modal efficiency. On this basis, the UAE's investment in bonded, AI-enabled land-corridor infrastructure is best understood as a strongly supported indicator of resilience-enhancing logistics capacity rather than as proof of a universally achieved operational outcome.

This finding has two broader implications. First, it demonstrates that carbon performance is partly an infrastructure outcome rather than solely an operational choice by firms. Where public and quasi-public actors invest in bonded corridors, port connectivity, digital customs processes, and modal integration, they effectively lower the emissions intensity of all corridor users. Second, the evidence suggests that resilience and decarbonization should not be treated as competing priorities. The traditional view assumes redundancy raises costs and therefore weakens green performance. However, where alternative routes and modes are digitally coordinated, resilience can reduce idle time, congestion, detours, and emergency rerouting, thereby improving both environmental and economic efficiency. This reinforces the thesis proposition that sustainable mineral corridors are built through governance-intensive infrastructure, not infrastructure alone.

Chapter 8: Discussion (Critical Synthesis)

8.1 The "Sovereign Investment Partnership" (SIP) as an ESG Engine

The study interprets the £30 billion SIP not as a mere financial arrangement, but as a **structural mechanism with the potential to advance sustainability convergence**. This conclusion is derived from the policy logic linking strategic capital, industrial upgrading, and standards adoption across the corridor discussion. On that basis, the analysis argues that such capital can function as a catalyst for "Green Standardization" where funding access is tied to auditable sustainability frameworks such as the USFMS (Unified Strategic Framework for Mineral Sustainability). The claim is therefore not that capital alone guarantees decarbonization of the midstream, but that standards-linked sovereign investment provides a plausible governance mechanism through which midstream decarbonization can be accelerated.

Seen through this lens, sovereign capital performs a disciplinary as well as developmental function. It disciplines by linking access to funding, industrial land, logistics platforms, or procurement opportunities with compliance to agreed sustainability metrics. It develops by reducing the transition costs associated with new reporting systems, cleaner transport technologies, digitized certification, and processing upgrades. This dual role is important because many actors in the mineral midstream are willing to improve but constrained by capital intensity, fragmented standards, or uncertainty regarding future regulation. A structured investment platform can therefore compress the time needed for standards adoption and reduce

the strategic hesitation that often delays sustainability upgrades. In this sense, the Sovereign Investment Partnership is not only a financing instrument; it is a governance accelerator that aligns strategic capital with corridor-wide ESG convergence.

8.2 The "Aberdeen-Fujairah" Bridge

The discussion compares the Aberdeen ETZ (focused on maritime decarbonization and high-tech mineral processing) with the Fujairah hub (focused on bulk consolidation and refining). Taken together, the available infrastructure and institutional evidence suggests that the synergy between these two locations could form the corridor's critical "connective tissue." The thesis therefore argues that **geographic decoupling**—where extraction happens far from the final user—is only likely to be sustainable when the *Logistics Interface* between specialized nodes is digitally integrated, standards-aware, and operationally interoperable. This conclusion is derived from the observable complementarity of the two nodes rather than from an assumption that bilateral integration is already complete.

Functionally, the Aberdeen–Fujairah bridge illustrates how corridor specialization can reduce systemic inefficiencies. Aberdeen's Energy Transition Zone is being developed as a low-carbon industrial ecosystem connected to deepwater port infrastructure, innovation facilities, hydrogen capability, and specialist supply-chain support. Fujairah, by contrast, offers strategic Indian Ocean access, bunkering strength, storage, refining-adjacent capability, and route diversification outside key maritime bottlenecks. Their complementarity lies not in duplication, but in differentiated roles within a shared value architecture: one node adds technological upgrading and market-facing compliance capacity, while the other enhances throughput flexibility, consolidation, and routing resilience. For the thesis, this demonstrates that corridor sustainability is not dependent on making every node identical; rather, it depends on ensuring that differentiated nodes are interoperable, data-linked, and aligned to a common governance logic.

Chapter 9: Policy & Industrial Implications (Concrete Roadmap)

9.1 Recommendations for Policymakers

- **Harmonization of Carbon Accounting:** Governments must move beyond national carbon reporting and adopt a "Corridor-Based Accounting" standard that treats a trade route as a single emissions-producing entity.
- **Incentivizing "Midstream Beneficiation":** Shift tax incentives from raw extraction to local processing zones (Kezad/Aberdeen), which reduces the volume of mass-transportation of raw, low-value material.

Implementation, however, requires institutional sequencing. Corridor-based carbon accounting cannot succeed if customs data, shipping records, factory-level emissions information, and product identity systems remain administratively siloed. Policymakers must therefore treat interoperability as a public-policy objective and not simply as a private-sector technology issue. This implies coordinated standards

development, mutually intelligible certification schemes, shared data definitions, and incentives for logistics operators and processors to participate in auditable reporting structures. A phased approach may be most effective: first, standardize data requirements at major corridor nodes; second, link incentives to verified participation; third, expand from pilot minerals and selected routes to a broader corridor portfolio. Such sequencing would reduce compliance friction while building institutional trust among participating jurisdictions and firms.

9.2 Recommendations for Firms (e.g., Berkeley Services IFM)

- **Audit Readiness:** Companies must move toward "Audit-by-Design," where supply chain traceability is integrated into the ERP (Enterprise Resource Planning) software rather than handled as a post-facto compliance exercise.
- **Modal Optimization:** Prioritize "Corridor Partners" who have already deployed IoT-enabled, low-carbon transport fleets.

At firm level, the strategic implication is clear: sustainability capability is becoming a source of commercial differentiation rather than a peripheral reporting exercise. Firms that can evidence chain-of-custody integrity, transport emissions performance, supplier due diligence, and route resilience will be better positioned to win contracts in premium markets and attract lower-cost finance. This requires new internal capabilities, including data governance, cross-functional ESG literacy, supplier onboarding processes, and the ability to integrate logistics, procurement, compliance, and finance within a common decision framework. For service providers operating in industrial ecosystems, the opportunity is especially significant: they can move from being cost-focused operators to becoming assurance-enabled partners that help clients manage corridor risk, maintain audit readiness, and demonstrate credible sustainability performance.

Chapter 10: Conclusion

This thesis has argued that the sustainability of critical mineral trade can no longer be understood adequately through mine-site performance or firm-level reporting alone. Instead, sustainability is increasingly produced through corridor-level configurations that combine infrastructure, standards, finance, and data interoperability. Using the UAE–UK case, the study has shown that logistics is not a neutral background condition but a core determinant of carbon exposure, resilience capacity, due-diligence readiness, and ultimately market legitimacy. The corridor perspective therefore redefines the geography of mineral sustainability: not as a linear path from extraction to consumption, but as a strategically governed architecture in which different nodes contribute specialized functions to a common low-carbon and traceable system.

The findings suggest that three conditions are especially important for future corridor competitiveness. The first is interoperable traceability, because sustainability claims are increasingly only as credible as the data systems that support them. The second

is governance-intensive logistics, because route resilience and emissions performance depend on public and quasi-public coordination as much as on private operational efficiency. The third is strategic capital aligned with standards adoption, because many sustainability improvements in the midstream require upfront investment, shared benchmarks, and credible long-term signals. Together, these conditions indicate that corridor success is not a product of geography alone. It is the result of institutional design. This is the central insight of the thesis and its main contribution to debates on mineral security, industrial policy, and ESG governance.

Future research could deepen and test this framework in several ways. Comparative work could examine whether similar corridor dynamics are emerging in other strategic pairings, such as Gulf–Europe, Australia–Asia, or Africa–Middle East routes. Empirical studies could introduce interviews, shipment-level data, lifecycle emissions accounting, or customs and certification datasets to assess how corridor governance performs under real commercial conditions. Additional research could also explore the political economy of inclusion: which producers are able to meet corridor standards, which are marginalized by new data and compliance demands, and how transitional support can be designed to avoid reinforcing global inequality. These avenues would help move the corridor concept from a strong doctoral framework to a wider research agenda with direct policy and industrial relevance.

Doctoral "Value-Add" Statement

To the author's knowledge, this thesis offers one of the earliest sustained doctoral analyses of the UAE–UK mineral corridor and reorients the debate from a predominantly ethics-centered discussion toward a more integrated account of strategic logistics, ESG governance, and digital traceability. Rather than making unqualified claims of empirical finality, the study's doctoral value lies in the originality of its conceptual framework and in its evidence-based interpretation of how digital visibility and corridor design shape sustainability outcomes in emerging sovereign-level mineral trade.

More specifically, the thesis makes four contributions. First, it develops the mineral corridor as a conceptually integrated unit of ESG and governance analysis, thereby shifting attention from firm-level sustainability to route-level institutional design. Second, it argues—on the basis of comparative policy, institutional, and infrastructure evidence—that logistics should be treated not as an auxiliary variable but as a co-determinant of mineral legitimacy, price formation, and market access. Third, it brings sovereign investment, industrial zoning, and digital traceability into a single explanatory framework for corridor competitiveness, highlighting their interdependence rather than treating them as separate policy domains. Fourth, it provides a policy-relevant interpretation of how emerging UK and UAE strategies may generate new forms of institutional convergence across critical mineral supply chains. Taken together, these contributions are intended to be conceptually original, empirically grounded, and extensible for future comparative research.

CLOSING PAGE

THE STRATEGIC INTERFACE OF SUSTAINABLE TRANSPORT, ESG GOVERNANCE, AND DIGITAL TRACEABILITY IN TRANSNATIONAL MINERAL CORRIDORS

A COMPARATIVE ANALYSIS OF THE UAE–UK STRATEGIC PARTNERSHIP

THIS THESIS IS RESPECTFULLY SUBMITTED AS A CONTRIBUTION TO THE STUDY OF SUSTAINABLE TRANSPORT, STRATEGIC MINERAL GOVERNANCE, AND DIGITALLY ENABLED CORRIDOR FORMATION.

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END OF THESIS