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DIGITAL TRANSFORMATION IN RAIL FREIGHT: LEVERAGING IOT AND BLOCKCHAIN FOR OPTIMIZING THE CHINA-EUROPE EXPRESS RAILWAY

Abstract: *The China-Europe Express Railway has grown into a corridor carrying more than three million TEUs annually, yet its continued efficiency gains increasingly depend on digital rather than physical infrastructure. This article examines how the Internet of Things (IoT) and blockchain are being applied to optimize the corridor's cargo visibility, customs clearance, and documentation processes. Drawing on recent industry and academic literature, the study finds that IoT applications — from satellite-based container tracking to wagon-condition sensors — are already deployed at meaningful scale, while blockchain applications remain comparatively nascent, concentrated in customs and trade-documentation pilots. The two technologies are shown to be complementary rather than substitutable: IoT generates the real-time operational data that blockchain-based systems require to create trustworthy, shared, and auditable records among the corridor's many independent railway administrations, customs authorities, and freight forwarders. The analysis concludes that sequencing IoT investment ahead of blockchain deployment is the more pragmatic near-term pathway.*

Keywords: *rail freight digitalization, supply chain visibility, China-Europe Express Railway, Internet of Things, blockchain, smart contracts, customs procedures*

1. Introduction and Literature Review

The China-Europe Express Railway operates across a fragmented institutional landscape — multiple railway administrations, customs regimes, and legal traditions — that has historically limited end-to-end cargo visibility. IoT-based tracking addresses this directly: wagon-mounted sensors enable constant position and condition monitoring (Kinéis, 2025), though fewer than 20% of the world's freight wagons currently carry such tracking, with wagons idle 30–40% of their lifecycle due to inadequate location data (Computools, 2026). China has tested a BeiDou-3 satellite-linked tracking device on the corridor to address cargo theft (South China Morning Post, 2026). Blockchain's application is narrower and concentrated in customs: customs authorities show the greatest institutional resistance to process change despite the corridor's low procedural harmonization (Nikolova, Roso, & Woxenius, 2020), while blockchain-based smart contracts automate payments and compliance once conditions are met (FreightAmigo, 2026). Few sources treat IoT and blockchain together as an integrated digital stack for this corridor — the gap this article addresses.

2. Methodology

This is a qualitative comparative literature review (2019–2026) combining technology-specific literature on IoT tracking and blockchain-based customs/trade systems, corridor-specific case evidence (the BeiDou tracking trial, Silk Road cargo-monitoring services), and a comparative assessment of adoption maturity, institutional barriers, and complementarity. Because peer-reviewed, corridor-specific blockchain research is limited, the blockchain component draws more heavily on industry sources than the IoT component — an asymmetry treated explicitly below.

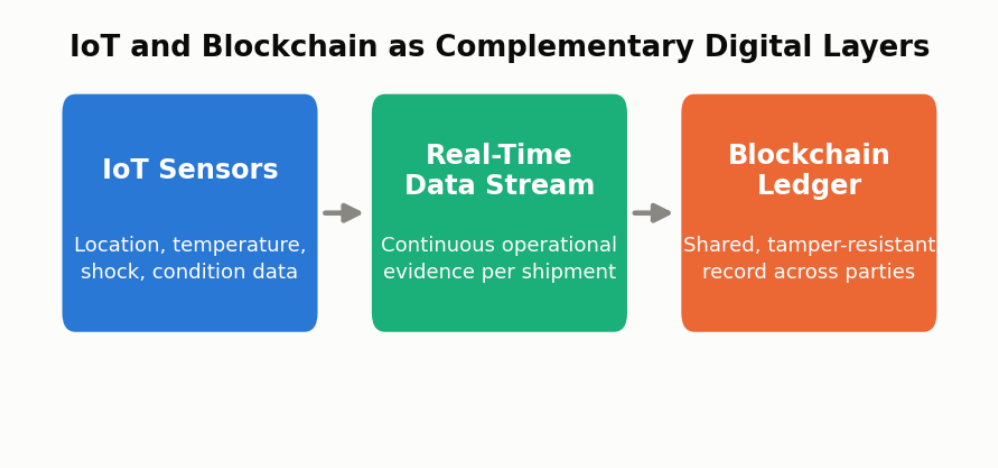

Figure 1. IoT and blockchain function as complementary digital layers: sensor data becomes the trusted record.

3. Results and Discussion

Table 1 compares the two technologies' corridor status, primary use cases, and key adoption barrier.

Table 1. IoT vs. blockchain on the China-Europe corridor.

Technology	Corridor Status	Primary Use Cases	Key Barrier
IoT	Operational, scaling (BeiDou-3 trial; commercial cargo monitoring)	Container/wagon tracking, condition monitoring, security	Capital cost — <20% of global fleet instrumented
Blockchain	Nascent — customs and trade-documentation pilots only	Smart contracts, shared customs ledgers, trade finance	Institutional resistance from customs authorities

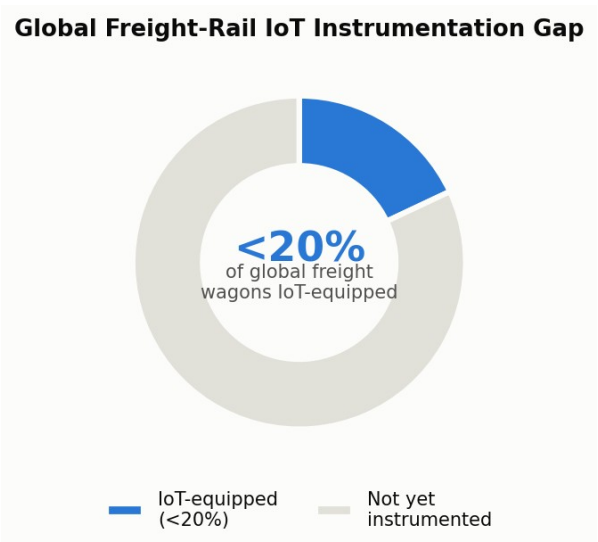

Figure 2. Fewer than 20% of the world's freight wagons carry IoT tracking, leaving substantial headroom for adoption (Computools, 2026).

IoT applications have progressed furthest in container and wagon-level tracking: the BeiDou-3 trial targets the corridor's cargo-theft vulnerability with continuous satellite positioning, complemented by commercial services such as Arviem's monitoring for Silk Road shipments. Blockchain's most-cited application is customs and cross-border documentation, since customs procedures are the least harmonized element of the corridor's institutional architecture (Nikolova, Roso, & Woxenius, 2020); a shared ledger would let customs authorities, operators, and forwarders access one authenticated shipment record and let smart contracts release goods once conditions are verified. The two technologies are complementary — IoT generates the real-time evidentiary data, blockchain provides the shared, tamper-resistant ledger to trust it (DHL Freight, 2023) — but face different barrier types: institutional-political for blockchain (customs resistance), capital-cost for IoT (fleet-wide instrumentation).

4. Conclusion

IoT and blockchain occupy different points on the maturity curve on the China-Europe corridor while remaining functionally complementary. IoT-based tracking has moved from pilot to meaningful operational deployment, though considerable adoption headroom remains industry-wide. Blockchain, concentrated in customs and documentation, remains comparatively nascent — constrained less by the technology's maturity than by institutional resistance and the number of independent systems any shared ledger must reconcile. IoT investment can therefore proceed largely independently and deliver near-term value, while blockchain-based customs integration will require sustained multilateral coordination; sequencing IoT ahead of blockchain, so the data it would need is already being generated, is the more pragmatic near-term pathway.

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