Evaluating Blockchain-Enabled IoT Solutions: Mitigating Spare Parts Challenges through Decentralized Supply Chain

Research Summary and 2026 Landscape Reassessment

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Updated July 2026

Abstract

The Spare Parts Problem is the standing trade-off in capital-goods maintenance between the cost of holding inventory and the cost of unplanned downtime. It is made harder by intermittent demand and by asset data that sits scattered across company boundaries. My MSc dissertation (University of Salford, 2024) asked whether blockchain-coordinated IoT could ease that constraint, and evaluated three architecturally distinct platforms for inter-organizational data sharing: VeChain, Helium, and Hyperledger Fabric. Using Multi-MOORA multi-criteria decision analysis across nine criteria, with weights set by pairwise comparison and decentralization deliberately modeled as a cost rather than a benefit, Hyperledger Fabric ranked first, ahead of Helium, with VeChain third. Fabric won on its permissioned architecture and native privacy controls. This paper summarizes the original study and tests its conclusions against what actually happened to each platform through mid-2026. The ranking holds. More interestingly, EU regulation, in particular the Digital Product Passport regime, has started to mandate the kind of cross-boundary data infrastructure the dissertation argued for.

1. The Spare Parts Problem

Spare parts management is where economics and information collide. Demand for any individual part is intermittent and lumpy, which defeats conventional time-series forecasting. The data that would improve those forecasts (installed-base size, operating conditions, real-time asset health) is generated by the companies operating the equipment, yet needed by the suppliers and maintenance providers who stock the parts. And the cost of getting it wrong is asymmetric: a stockout that idles a production line costs far more than carrying the part that would have prevented it.

The dissertation's core diagnosis was that the bottleneck is no longer technical. Condition-monitoring hardware for vibration, temperature and usage is mature and cheap. What's missing is institutional: firms won't share operational data across corporate boundaries without credible guarantees about who sees what, when, and on whose authority. So I treated blockchain not as a database but as a governance technology, an immutable and auditable substrate where selective disclosure between counterparties is enforced by the architecture itself instead of by contract alone.

2. Research Design

I picked the three platforms to cover the design space, not cluster inside one paradigm. VeChain is a public enterprise chain with a dual-token fee model, a permissioned-sidechain option, and a genuine track-and-trace portfolio. Helium is a decentralized physical infrastructure network (DePIN) offering

low-cost LoRaWAN connectivity for IoT devices. Hyperledger Fabric is the reference open-source framework for permissioned, consortium-governed ledgers. One public chain, one connectivity network, one consortium framework: three different answers to the same question.

The criteria came out of the literature review, not a template. Nine in total: scalability-to-cost, transaction fees, IoT integration, on-chain data storage, security, privacy, two measures of development health (mean lifetime GitHub commits and commit authors, extracted with the GrimoireLab analytics toolset and grounded in the open-source-success literature), and decentralization. One design choice matters more than the rest. Decentralization was the study's only non-beneficial criterion. Most blockchain comparisons treat it as an unqualified virtue; for inter-organizational spare-parts data, where firms cooperate precisely because they can control who reads and writes what, more decentralization means less of that control, so the analysis scored it as a cost.

Weights came from an Analytic Hierarchy Process pairwise comparison, checked with a sensitivity analysis at a tolerance of 0.12. Security carried the largest weight and decentralization the smallest. Each platform was then scored against each criterion: binary satisfaction judgments for the qualitative categories, quantitative figures (fees, setup costs, repository metrics) where public data allowed, all drawn from block explorers, project documentation and GitHub. The scores ran through Multi-MOORA's weighted-ratio aggregation to produce the final ranking. The framework is deliberately reusable, for other platforms or for later versions of the same ones. This reassessment leans on that.

3. What the Analysis Found (2024)

The final ranking, in descending order: Hyperledger Fabric, Helium, VeChain. What decided it was not security, where all three tied despite it carrying the heaviest weight, but privacy. Fabric's Membership Service Providers, Access Control Lists and policy layer let a consortium write commercial confidentiality directly into the network topology, natively, inside the SDK. A supplier can verify that a part's condition data exists, and act on it, without the operator exposing that data to competitors on the same network. Helium and VeChain can approach similar guarantees only through third-party integrations and extra developer work. Since the real obstacle in spare-parts data sharing is trust, not throughput, that native capability settled first place.

Helium took second on economics and ecosystem. Entry costs are close to trivial: a compatible hotspot for around $110, a small private industrial LoRaWAN network server running over Helium for roughly $1,600, and device traffic at about a dollar a year on five-minute reporting intervals. It also had the largest catalog of ready-to-use LoRaWAN devices and the heaviest development activity on both GitHub measures. Its weak spot was on-chain data storage, where anything complex needs off-chain solutions, pushing cost back toward developer time.

VeChain came third, for instructive reasons. Its public mainnet is cheap to use and its traceability record is real, but the permissioned route the Spare Parts Problem calls for ran through an Authority Node, with close to a million dollars of VET locked as collateral at the time of writing. And ToolChain, the enterprise product where VeChain's supply-chain strength actually lives, is closed-source, so it couldn't be analyzed at all. The thesis was equally blunt about the winner's flaw: Fabric's expensive custom build recreates, in miniature, the very coordination problem it is meant to solve, because consortium members must first agree on how to split the bill.

The synthesis: no single platform covers sensing, transport and governance. The study therefore backed hybrid architectures, with decentralized IoT networks handling data acquisition and permissioned ledgers handling inter-organizational governance, and recommended Fabric as that governance layer.

4. The 2026 Landscape, Platform by Platform

4.1 Hyperledger Fabric. Fabric is still the reference permissioned framework, now stewarded within LF Decentralized Trust after the Hyperledger Foundation folded into that broader Linux Foundation body in late 2024. Two technical developments matter for the 2024 criteria. The v3.0 release introduced a Byzantine fault-tolerant ordering service built on the SmartBFT library: for the first time, Fabric can tolerate ordering nodes that behave maliciously, not just ones that crash, as long as they stay below a third of the set. In the study's terms that lands on security, the heaviest-weighted criterion, and it strengthens the permissioned model on its own terms, since a consortium no longer has to extend full trust to every ordering node it admits. The v3.1 line, now the project's long-term-support release (v2.5 LTS is maintained in parallel), added batched state-read APIs that speed up chaincode for read-heavy workloads, which is exactly the access profile of telemetry applications. Patch releases were still shipping in June 2026. On every criterion that decided the 2024 ranking, Fabric has held its ground or gained.

4.2 VeChain. VeChain has delivered two of the three phases of its Renaissance roadmap. Galactica (mainnet, July 1, 2025) swapped static pricing for a dynamic, EIP-1559-style fee market with base-fee burning, and brought the execution environment level with Ethereum's Shanghai-era EVM. Hayabusa (mainnet, December 2, 2025, at block 23,414,400) then retired the original Proof-of-Authority consensus for Delegated Proof-of-Stake with a 101-validator set, NFT-based staking through StarGate, and VTHO issuance tied to staked VET and network usage. Stakeholders approved the change with roughly 98 percent of votes in August 2025. A third phase, Interstellar, targeting full JSON-RPC and EVM equivalence, is in development for 2026.

For my criteria, the movement that matters is barrier to entry. VeChain ranked last in 2024 largely because its permissioned route ran through Authority Nodes and their million-dollar collateral. Hayabusa retired that model, and staking through StarGate restructures the economics of participating in consensus, which attacks the exact objection that sank VeChain in the original scoring. Fee behavior changed character too, from fixed to demand-responsive, trading some of the absolute predictability I originally credited for efficiency. What has not changed is ToolChain: still the packaged enterprise offering, still closed-source, still resistant to independent analysis, so the 2024 caveat stands. Walmart China's food traceability and BMW's parts-provenance work persist, and the integration with Franklin Templeton's BENJI tokenization platform signals an institutional turn. Token price stays decoupled from on-chain utility, as it was in 2024. For an infrastructure evaluation, that was never the question.

4.3 Helium. Helium is the complicated one, and the fair way to read it is to separate the network from the company. The network first: the LoRaWAN sub-network keeps operating at global scale, and participation got cheaper in April 2025, when hotspot onboarding dropped to $10 and location assertion to $1 in data credits. Tokenomics were simplified in January 2025, when HIP-138 consolidated rewards from all sub-networks into HNT, retiring the IOT and MOBILE sub-token voting structure the 2024 analysis had to describe. A real regulatory overhang cleared in April 2025, when the U.S. Securities and Exchange Commission dismissed its claims against Nova Labs.

The company is a different story. Its strategic center of gravity has moved to mobile: the pivot from IoT connectivity to Wi-Fi carrier offload is the explicit subject of two Harvard Business School case studies (2024–2025), and mid-2026 brought a leadership transition, with the founder moving to a chairman role under a newly appointed chief executive, alongside the announced sale of the consumer cellular business. The thesis flagged Helium's token-holder governance as both an asset and a risk demanding stakeholder time; the last eighteen months read like that risk expressed at corporate scale. None of it breaks what the 2024 analysis valued Helium for, which was cheap, standards-based sensor transport. That still works, and now costs less. But anyone building on it should price in strategic-continuity risk, softened by the fact that Class-A LoRaWAN devices aren't Helium-specific and can migrate to private or other public LoRaWAN networks without much pain.

5. Does the Ranking Survive 2026?

Yes, and for structural reasons, not luck. Security carried the largest weight in 2024, but all three platforms tied on it; the ranking was actually decided by privacy, and privacy is an architectural property. It moves slowly. The criteria that have moved fastest since 2024 (consensus design, token economics, corporate strategy) either improved for the platforms in question or shifted in ways that don't touch the spare-parts decision. Fabric strengthened its security story with BFT ordering without giving up the permissioned properties that made it dominant. VeChain attacked its real 2024 weakness, the barrier to entry, but its enterprise product remains closed to inspection. Helium's turbulence raises risk at the corporate layer without impairing the transport capability the analysis credited it for. Re-score it however you plausibly like: the ordering from the 2024 Multi-MOORA analysis comes out the same. Fabric, then Helium, then VeChain, with the second and third as complements to the first rather than substitutes for it.

6. What This Means in Practice

For practitioners the findings resolve into a reference architecture, not a product choice. Condition data comes in over low-cost LoRaWAN transport: Helium where public coverage suffices, private LoRaWAN where continuity risk or coverage gaps say otherwise. Governance, selective sharing and audit live on a permissioned Fabric network, whose channels, access controls and private data collections map onto the consortium's actual confidentiality constraints. Where provenance has to be verifiable by outsiders (resale, regulatory disclosure, anti-counterfeiting), a public chain with a production traceability record, VeChain being the obvious candidate, can serve as an anchoring layer.

The strongest new argument for that architecture is regulatory. The EU's Ecodesign for Sustainable Products Regulation has been in force since July 2024 and mandates Digital Product Passports on a phased schedule: the central EU DPP registry goes live in July 2026, battery passports become mandatory for industrial and EV batteries above 2 kWh from February 2027, and delegated acts extend coverage to further product groups through 2030. A Digital Product Passport is, in effect, a legally required version of what the dissertation argued for: structured, auditable, selectively accessible product data that follows an asset across organizational boundaries for its whole life. Spare-parts provenance, installed-base records and maintenance histories are natural extensions of passport data. Companies standing up DPP compliance pipelines are building the data infrastructure the Spare Parts Problem has always lacked, whether that's the intent or not. The claim at the center of the thesis, that inter-

organizational data flow and not sensing technology is the binding constraint, is turning into a compliance requirement.

7. Limitations and Where This Goes Next

Three limitations frame the agenda, and I'd rather name them than have a reader find them. First, the evaluation ran at platform level. Deployment-level performance inside a specific consortium, with real data volumes and real adversarial incentives, remains untested. The obvious next step is a field pilot: an instrumented asset fleet writing condition data over a LoRaWAN transport layer into a Fabric consortium channel, with forecast accuracy and inventory outcomes measured against a conventional baseline. Second, criterion scores describe fast-moving systems at a moment in time. The 2024 conclusion said so itself: “There may be significant changes to any of these blockchains at the current time this paper is being read.” This update is that sentence taken seriously, and the exercise should repeat, next time including candidates that sat outside the 2024 scope. IOTA is the obvious one: excluded then as a DAG rather than a conventional blockchain, it has since shipped a full protocol relaunch and has earned a seat in the next scoring round. Third, the study addressed whether inter-organizational data sharing is feasible, not whether it's economical. Total cost of ownership, and above all the incentive design that would make operators willing, not merely able, to share data, are open problems. The thesis also pointed at the sensor layer: the vibration monitoring it drew on covers only some failure modes, and pairing wider environmental sensing (temperature, humidity, regional patterns) with shared data could surface failure drivers no single firm can see alone. Fold in the convergence of Digital Product Passport schemas with consortium ledger design, plus predictive-maintenance models trained on shared IoT data, and the 2024 question is no longer whether this stack can exist. It's who assembles it first.

Provenance

This summary draws on my MSc dissertation (12,088 words, University of Salford, 2024, supervised by Dr. Vesna Sedoglavich). Platform developments were verified against project documentation, release records and regulatory sources current to July 2026. For the full thesis, contact me or consult the University of Salford institutional repository.