

How Distributed Ledger Technology supports the transition to Autonomous Mobility

Innovation



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Alstom regularly evaluates new technologies. In this paper, we are taking a closer look at the potential impact Blockchain may have on rail.

The railway industry is in a new era of digital transformation, driven by the need for resilience, automation, and secure data exchange across increasingly complex ecosystems. Blockchain – more precisely, Distributed Ledger Technology (DLT) – is emerging as a foundational infrastructure for enabling trust, transparency, and interoperability in these environments.

But can Blockchain support the transition to Autonomous Mobility?

Originally developed to secure decentralised financial transactions, blockchain has evolved into a versatile infrastructure technology. Its core strengths – immutability, consensus-based validation, and cryptographic security – are now being used to address challenges related to trust, data integrity, and multi-party coordination.

In mobility and industrial environments, DLT can help:

- Remove intermediaries in multi-stakeholder processes
- Guarantee data integrity across distributed systems
- Enable machine-to-machine transactions in automated settings
- Provide tamper-proof audit trails supporting regulatory compliance

These capabilities align well with the characteristics of the railway sector: long-lifecycle assets, stringent safety and certification requirements, and fragmented operational responsibilities. DLT could help unify data flows between operators, infrastructure managers, OEMs, and regulators – without compromising safety or data sovereignty.

Strategic Drivers in Rail

Over the past couple of years, there have been developments within the rail industry, which could further accelerate:

- **Increased need for Operational Resilience:** With aging infrastructure and workforce shortages, scalable and secure retrofitting is essential
- **Emergence of Autonomous Mobility:** Blockchain supports decentralised coordination and trust between machines, potentially enabling safe and scalable autonomous train operations
- **Compliance with Data Laws and Data Sovereignty:** Blockchain ensures tamper-proof data provenance, aligning with GDPR, EN50159, and emerging standards for trustworthy AI
- **Interoperability & Ecosystem Integration:** Blockchain enables seamless coordination across institutional and technical boundaries, supporting initiatives like Gaia-X and the EU Mobility Data Space
- **Safety:** Will always be the No. 1 priority in rail ecosystems. Some legacy rail system are still prone to external impacts or human error. Accelerated digitalisation of such legacy systems may be enabled by DLT technology.

For **Autonomous Mobility, Blockchain** can help establish trust between systems. It can securely validate critical data – such as digital maps used for routing and perception – and can strengthen juridical recorder functions by ensuring that recorded information cannot be altered.



CASE STUDY

Blockchain Data Logger

Data loggers play a critical role in the rail industry by capturing and storing operational data from trains and infrastructure systems. Their use spans across safety, maintenance, performance monitoring, and regulatory compliance. The logs are used for various applications:

- **Safety Monitoring:** Initiating alerts in case of abnormalities
- **Reliability Management:** Condition Monitoring and Fault detection
- **Operational Performance:** Energy Efficiency and timetable adherence
- **Regulatory Compliance and Auditing:** provide evidence for audits, investigations and compliance with safety standards (e.g. ERA, FRA or national regulations)
- **Juridical Recorders:** capture data like speed, brake pressure, throttle position, and signal aspects before, during, and after incidents.

With the emergence of **Autonomous Trains**, Artificial Intelligence and respective regulation, the question of data provenance and trustworthiness becomes ever more prominent.

In the future, data validation across multiple stakeholders will become even more important with Autonomous trains, using digital maps provided from different entities or the requirement to replace human testimony with technology: A solution may be a tamper-proof, blockchain-anchored unit that logs and notarises safety-critical events and supports legal traceability, real-time diagnostics and fleet-wide standardisation.

In partnership with 51nodes, a concept was developed to tokenise videos recorded from the cabin, and it was demonstrated that DLT can be used to ensure data integrity and provenance.

As a second step, the data was then analysed using AI and data anonymisation methods. This would allow to derive insights from onboard data loggers, while respecting GDPR and other EU legislation.



From an architecture perspective, the given use case was delivered based on two available “off-the-shelf” solutions:

- **World Mobile Chain:** Provides edge-level hashing and timestamping for event data
- **Rivalz AI:** Enables onboard visual recognition and anomaly detection

As part of a pilot project, the technical feasibility of the use case was successfully demonstrated. For this purpose, a train was equipped with a bundle of sensors to record video streams, positional data, and timestamps. The collected data was transmitted to an external cloud via a software application for further processing.

The key innovation was ensuring data provenance through cryptographic hashing and timestamping, which allows the origin of data to be proven in a legally admissible manner. At the same time, video data was processed in a prototype phase using AI-powered object recognition. This confirmed the functionality of all modules relevant to the use case.

In addition, important insights were gained for further development, including optimising the sensor data stream, data management, and hardware configuration. Data processing already took regulatory requirements (such as GDPR) into account by consistently anonymising individuals and vehicle license plates.

The Future

As railways evolve to meet the demands of increased automation, resilience, and regulatory oversight, blockchain technology stands out as a promising enabler for a secure and interconnected digital ecosystem. By harnessing distributed ledgers, the railway industry can achieve new standards of trust, transparency, and operational efficiency across diverse stakeholders.

However, realising these benefits requires careful navigation of technical, regulatory, and organisational challenges. While blockchain's potential is significant, its successful integration will depend on industry collaboration, ongoing innovation, and a willingness to adapt existing systems and standards.

Strengths and Weaknesses of Blockchain Technology for Rail



Enhanced Data Integrity and Security



Blockchain's immutable ledger provides tamper-proof records, increasing confidence in the accuracy and provenance of operational and safety-critical data.



Integration Complexity



Existing railway systems are highly regulated and standardised; integrating blockchain with legacy infrastructure and meeting compliance requirements presents significant technical and procedural hurdles.



Decentralised Coordination



By distributing control and validation across multiple parties, blockchain eliminates single points of failure and supports autonomous, machine-to-machine transactions essential for next-generation railway operations.



Resource and Scalability Concerns



Private blockchain deployments may demand substantial computing power and specialised hardware, potentially increasing operational costs and limiting agility compared to centralised solutions.



Streamlined Compliance and Auditability



Blockchain enables transparent, traceable records that facilitate regulatory compliance, support legal investigations, and simplify audits for both operators and authorities.



Regulatory and Acceptance Barriers



Gaining acceptance from authorities for blockchain-based safety-critical systems remains a challenge, especially when existing standards are not fully aligned with decentralised architectures.

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