THE ANNALS OF "DUNAREA DE JOS" UNIVERSITY OF GALATI
FASCICLE IX. METALLURGY AND MATERIALS SCIENCE
N°. 3 - 2025, ISSN 2668-4748; e-ISSN 2668-4756
Article DOI: https://doi.org/10.35219/mms.2025.3.04

# HOW BLOCKCHAIN CAN RESHAPE THE SUPPLY CHAIN OF STEEL FOR AN INDUSTRIAL COMPLEX

**Ștefănică FRANGU, Ioan ȘUȘNEA**
"Dunărea de Jos" University of Galați, Romania
e-mail: frangu.stefanica@gmail.com, ioan.susnea@ugal.ro

## ABSTRACT

*Steel is an integral part of modern infrastructure and is present in buildings, vehicles, and machinery. Although ubiquitous, the process of converting raw materials into usable products is highly advanced and, in almost all instances, largely unseen. Blockchain can ensure secure, transparent ledgers are maintained throughout each step of the process, from mining and processing to production and export. This enables companies to verify the origin of the steel, the processes undertaken during its production, and its conformity to safety and environmental standards.*

*This article demonstrates how blockchain is transforming the steel sector by accelerating, simplifying, and making the tracking process more environmentally friendly. It presents the advantages and disadvantages of applying digital technology to traditionally analogue businesses, based on real-world cases and research.*

*Readers will learn how a conventional business, with a history spanning centuries, is beginning to capitalize on digital opportunities - whether in manufacturing, IT, or even in industrial processes - making it especially relevant to those passionate about technology.*

KEYWORDS: steel, blockchain, supply chain, transparency

## 1. Introduction

The steel producing industrial complex from Galați (Figure 1), one of the foremost integrated steel manufacturers in Europe, has extensive inventories of semi-finished and finished steel products, such as coils, rebar, and structural profiles. It supplies these products to downstream consumers such as construction, automotive, and infrastructure industries.

***Fig. 1.*** *Steel-producing industrial complex* [1]

To date, the steel-producing industrial complex in Galați has supplied heavy plates for significant infrastructure projects, including: the Railway Bridge for Otopeni Airport—providing over 1,500 meters of plates for the new railway bridge between Bucharest North Station and Otopeni Airport, which enhances national transportation infrastructure [3]; the Danube Bridge at Brăila, which will be the third largest in Europe [2]; the bridges over Mureș River that are part of the A10 Sebeș – Turda motorway; and the "Osman Gazi" Bridge in Turkey [2].

To enhance traceability, regulatory compliance, and customer trust, a blockchain solution is proposed. This initiative covers part of the steel supply chain, ensuring auditable integrity of data from the production to delivery and creating value to the stakeholders who rely on authentic certification, origin traceability, and Environmental, Social, Governance (ESG) reporting.

While technological advancements have improved the manufacturing process, supply chain coordination still depends on outdated systems, fragmented databases, and a lack of transparency.

THE ANNALS OF "DUNAREA DE JOS" UNIVERSITY OF GALATI
FASCICLE IX. METALLURGY AND MATERIALS SCIENCE
N°. 3 - 2025, ISSN 2668-4748; e-ISSN 2668-4756
Article DOI: https://doi.org/10.35219/mms.2025.3.04

In contrast with markets targeting consumers, where blockchain adoption is going mainstream, the steel industrial environment comes with its own set of challenges: granularity of data, synchronization of physical to digital, and conservatism of established infrastructures.

## 2. Benefits of using blockchain

Blockchain is a distributed ledger, shared among all network participants, where all information can be seen in real time without concerns about the data being altered [4].

Major advantages of the application of blockchain in the steel supply chain are:

- Transparency

Anyone can view the blockchain ledger and anyone can take advantage of it. Everyone can see the ledger's changes in real time. Process transparency brings trust, making it more difficult to falsify information.

- Security and Immutability

Every block of a blockchain is also safely attached to the previous block, making data manipulation almost impossible to achieve undetected. Once data is irrevocably recorded, it cannot be changed unless the entire network concurs. Blockchain can't be easily hacked and modified due to the fact that it can't be modified.

- Decentralization

While classical systems depend upon a central authority, blockchain does not. It decentralizes the authority among a collection of nodes, removing single points of failure and the necessity of intermediaries. It promotes resilience, efficiency, and added system integrity.

- Traceability

With blockchain, these assets, data, or transactions can be tracked real-time throughout their lifecycle. It becomes incredibly vital in the field of supply chain management, as it provides end-to-end visibility, puts down counterfeiting, and verifies authenticity.

- Efficiency and Speed

When transactions are facilitated through the normal payment systems, it sometimes involves engaging numerous middlemen and also delays. Blockchain makes processes easier as people can make transactions among themselves securely and easily. It minimizes the cost and the time of transactions and operations.

- Cost Reduction

Blockchain helps reduce administrative costs at bay since it becomes less cumbersome to verify, keep track, and settle disagreements among other individuals. It also reduces labour costs associated with manual processes and eliminates errors resulting from manual data entry by enabling smart contracts to handle tasks automatically.

Applications (Figure 2)

Provenance and Traceability: Tracking materials from mines to mills to customers.

Quality Assurance: Recording and validating inspection certificates.

Inventory Management: Real-time tracking of shipments and storage.

Compliance and ESG Reporting: Proving adherence to Environmental, Social, and Governance standards.

Carbon Emissions Monitoring: Measuring and reporting $CO_2$ emissions across the supply chain and operations for sustainability tracking and regulatory compliance [5].

The implementation includes:

- Digitizing quality and logistics records for each batch of steel.

- Using blockchain to log certifications, production timestamps, and transport milestones.

- Integrating data from IoT sensors to verify temperatures, emissions, and compliance in real-time [6].

These innovations help build customer trust, improve regulatory compliance, and streamline audits.

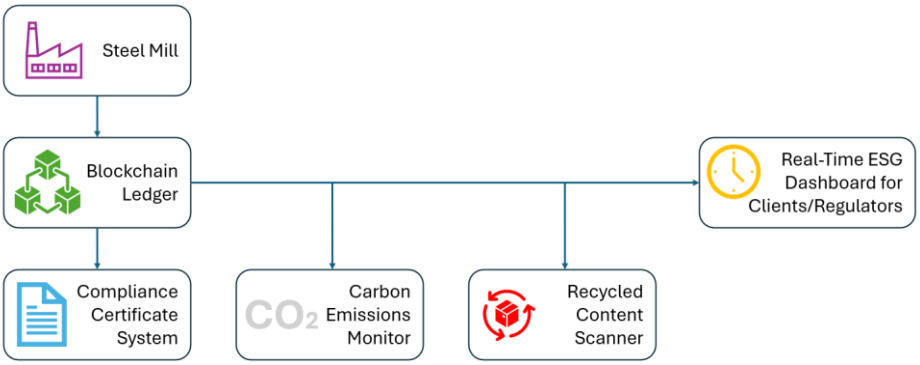


***Fig. 2.*** *Blockchain Ledger Applications*

THE ANNALS OF "DUNAREA DE JOS" UNIVERSITY OF GALATI
FASCICLE IX. METALLURGY AND MATERIALS SCIENCE
N°. 3 - 2025, ISSN 2668-4748; e-ISSN 2668-4756
Article DOI: https://doi.org/10.35219/mms.2025.3.04

Challenges: high initial installation cost, the need for standardization across the industry, resistance to change by current operators, data privacy, and compatibility with legacy systems.

## 3. Real world use cases

Several big companies across the world now employ blockchain in the steel supply chain. In addition, tools have been made to help manage and keep an eye on the steel manufacturing chain.

- Organizations

Gerdau and RHI Magnesita are using blockchain to track refractory performance contracts in steel production, automating measurements, boosting transparency, and replacing manual spreadsheets. The initiative was launched at a Gerdau site in Minas Gerais, Brazil [8].

Tata Steel uses blockchain to enhance traceability and sustainability in its supply chain, tracking from raw materials through to final product delivery [9, 10].

ArcelorMittal employs blockchain to verify the provenance of raw materials, ensure regulatory compliance, and manage sustainability data across its global supply chain [11].

POSCO International (South Korea) has rolled out a blockchain-based trade platform to digitize and streamline international shipping processes, particularly through the use of electronic bills of lading [12].

- Platforms

MineHub Technologies provides end-to-end digitization of mining and metals supply chains, including steel raw materials.

Refrac Chain (Gerdau + RHI Magnesita) is a blockchain platform designed for managing refractory performance contracts in the steelmaking process.

IBM Blockchain / TradeLens (with Maersk) focused on digitizing global logistics and shipping through blockchain.

TradeLens demonstrated the value of shared infrastructure and consortium governance. Its design separates on-chain permissions from off-chain governance, offering a roadmap for steel consortia. However, the project was discontinued in 2023 due to three main reasons: regulatory barriers, industry reluctance, and technical integration [7].

VeChain focuses on supply chain traceability using blockchain and IoT. While not specific to steel, it is used in manufacturing, logistics, and compliance-heavy industries like automotive, and has the potential to support steel traceability (e.g., tagging coils, verifying origin, tracking emissions).

Hyperledger Fabric (Framework) is an open-source blockchain framework for building custom, permissioned networks

## 4. Proposed Pilot Framework

A six-phase model (Figure 3) is proposed for initiating and scaling blockchain in the steel supply chain.

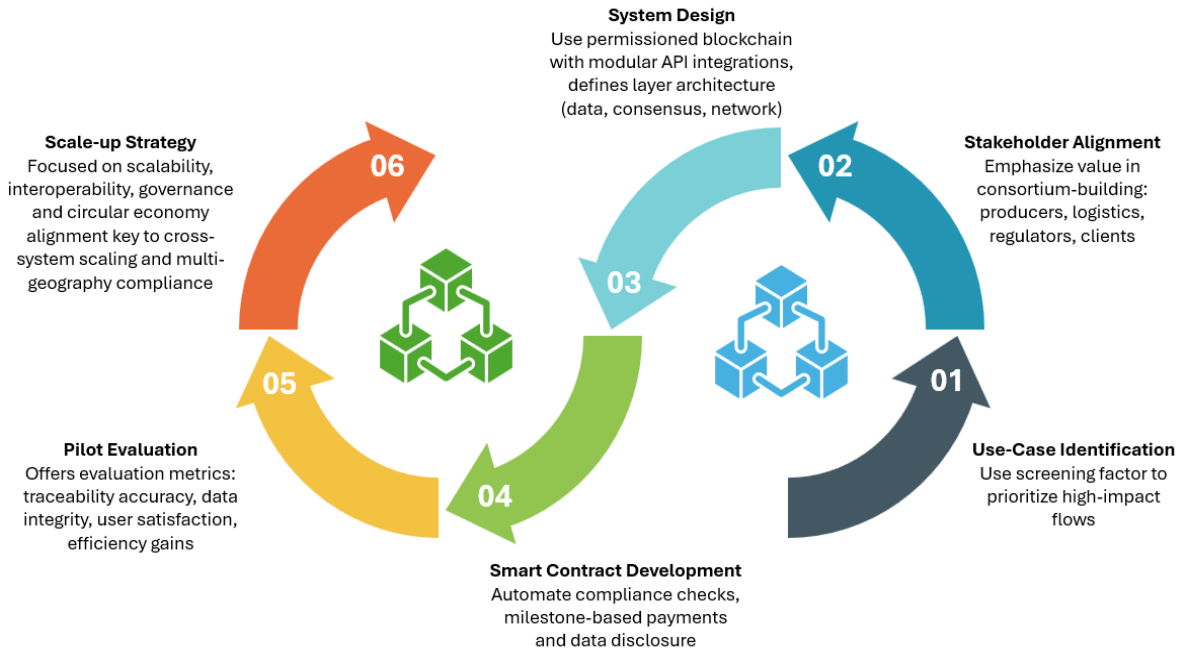


***Fig. 3.*** *Six phase model proposed*

THE ANNALS OF "DUNAREA DE JOS" UNIVERSITY OF GALATI
FASCICLE IX. METALLURGY AND MATERIALS SCIENCE
Nº. 3 - 2025, ISSN 2668-4748; e-ISSN 2668-4756
Article DOI: https://doi.org/10.35219/mms.2025.3.04

Use-Case Identification:

Phase one is the prioritization and shortlisting of high strategic and operational value use cases. There exist numerous complex flows for steel companies like recycled steel certification, conflict mineral tracking, or emission compliance that are very suitable for blockchain implementation. Organizations can quickly scope high potential use cases by filtering aspects like impact potential, data availability, existing inefficiencies, and regulatory imperatives.

Executive sponsorship is needed for alignment across business goals, as well as for cross-functional teamwork.

Stakeholder Alignment:

Optimal use of blockchain is achieved when there is a collective effort throughout the whole supply chain. This involves the development of an appropriate stakeholder consortium: steel mills, logistics providers, recyclers, regulatory commissions, and end users. Stakeholder alignment provides collective vision, good governance, and group incentives - all of which matter for the network effect to take hold.

It includes matching mutual pain points (e.g., absence of real-time traceability, divergent documentation, or greenwashing concerns) to blockchain functionalities. By enabling transparency and building trust among actors, stakeholder adoption is facilitated as a strategic enabler [14].

System Design:

Here, technical design choices lie behind the blockchain implementation. For the steel supply chain - with requirements for privacy, limited access, and audit trails - a permissioned blockchain like Hyperledger Fabric is ideal [15]. System design is organized into discrete, separate layers:

- Data Layer: Consists of virtual copies of physical goods (e.g., steel bundles, heat numbers, recycling history).
- Consensus Layer: Utilizes protocols that are appropriate for enterprise-grade performance (ex: Raft, PBFT) [16].
- Network Layer: It allows for node architecture among consortium participants alongside secure communications between peers.

Interoperability of Enterprise Resource Planning (ERP) and SCM applications (ex: Oracle, SAP) is facilitated through the adoption of Application Programming Interface (APIs), ensuring seamless data exchange and minimal disruption to already implemented IT infrastructure. This step also enables scalability, modularity, and interoperability as core design goals.

Smart Contract Development:

Smart contracts form the operational logic that makes processes self-automating and enforces rules that can:

- Automatically trigger payouts for milestones (e.g., payment upon confirmation of delivery).
- Implement compliance requirements (e.g., reporting of $CO_2$ emissions, validation of recycled content).
- Facilitate disclosure of real-time data to regulators and clients.
- Incorporate traceability events throughout the entire product lifecycle.

Pilot Evaluation:

Pilot implementation is also undertaken prior to large-scale deployment, to evaluate blockchain solutions under emulated conditions. Evaluation criteria include:

- Traceability Accuracy: Ability to track steel products and chain input capability.
- Data integrity: Prevention of tampering and unauthorized access.
- User Satisfaction: Adoptability rate, quality of user interface, and confidence in the system.
- Efficiency Gains: Reduced paperwork, audit times, and dispute resolution efforts [13].

Scale-up Strategy:

Phase six is scaling up the blockchain network for sustained performance, regulatory compliance, and alignment with circular economy values. The scale-up approach includes:

- Scalability: Optimizing network size, capacity, and smart contract throughput.
- Interoperability: Enabling compatibility with other blockchain platforms (e.g., customs platforms, carbon registers).
- Governance: Defining rules for network engagement, participant additions, and conflict resolution.
- Sustainability Integration: Introducing circular economy aspects such as recycling traceability, carbon steel certification, and lifecycle reporting.

Steel's adoption of blockchain is still in its early stages, but remains highly promising. To have a significant effect, industry stakeholders must develop standards and procedures for shared data, foster cross-industry partnerships, invest in digital capacity and infrastructure, and prioritize blockchain deployment aligned with ESG and circular economy goals.

Governments and industry regulators must standardize data formats and incentivize blockchain adoption via Environmental, Social and Governance credits and tax relief. Steel producers should explore open consortia to reduce costs and redundancy. Research institutions can contribute by developing simulation environments to test cross-platform interoperability and governance risk.

THE ANNALS OF "DUNAREA DE JOS" UNIVERSITY OF GALATI
FASCICLE IX. METALLURGY AND MATERIALS SCIENCE
No. 3 - 2025, ISSN 2668-4748; e-ISSN 2668-4756
Article DOI: https://doi.org/10.35219/mms.2025.3.04

## 5. Conclusions

Although the steel-producing industrial complex from Galati hasn't employed blockchain technology as of yet, the idea of implementing such a system is an unconventional solution to the inefficiencies of steel supply chain structures. As convoluted as figuring out production, logistics, regulatory, and certification processes between multiple parties may be, blockchain is a secure, auditable, and decentralized solution to ensuring data integrity and enabling interoperability.

With the adoption of permissioned blockchain platforms (e.g., Hyperledger Fabric), the steel industry can achieve detailed, end-to-end movement traceability, tamper-evident certification histories, and automation of rules through smart contracts. Interoperability between existing IoT infrastructure and ERP/SCM applications via APIs enables dynamic, real-time monitoring of emissions, quality measures, and logistics events, minimizing human intervention and optimizing system responsiveness.

The realization of these benefits, however, is contingent upon cross-industrial cooperation, standard definition, and alignment of stakeholder interests - most significantly around data models, rules of governance, and application interoperability. Pilot implementations and evaluations also play an essential role in demonstrating system performance under real-world conditions before scaling to production environments.

In the sector, and for the steel-producing industrial complex in Galați as it considers options for digital transition, blockchain is an appropriate starting point for enhancing supply chain visibility, supporting ESG reporting, and achieving circular and low-carbon steel production - with a target of reducing carbon emissions by 2030.

## References

**[1].** ***, https://libertysteelgroup.com/ro/companie/istorie/, accessed in 27.06.2025.
**[2].** ***, https://libertysteelgroup.com/ro/produse/, accessed in 27.06.2025.
**[3].** ***, https://www.romaniajournal.ro/business/liberty-galati-steel-part-of-the-new-railway-route-connecting-the-north-station-to-otopeni-airport/, accessed in 27.06.2025.
**[4]. Imran Bashir, Mastering Blockchain**, *A technical reference guide to the inner workings of blockchain, from cryptography to DeFi and NFTs*, Fourth Edition, p. 11-23, p. 221-241, 2023.
**[5]. Muhammad Salman Asif, Harsimran Gill**, *Blockchain Technology and Green Supply Chain Management (GSCM) – Improving Environmental and Energy Performance in Multi-echelon Supply Chains*, DOI: 1088/1755-1315/952/1/012006, 2022.
**[6]. Yan Cao, Feng Jia, Gunasekaran Manogaran**, *Efficient Traceability Systems of Steel Products Using Blockchain-based Industrial Internet of Things*, DOI: 10.1109/TII.2019.2942211, 2019.
**[7]. Babu George**, *Blockchain in Global Trade: Insights from the TradeLens Experiment*, DOI: 10.31235/osf.io/apsz9_v1, 2025.
**[8].** ***, https://www.rhimagnesita.com/rhi-magnesita-and-gerdau-leading-the-way-in-using-blockchain-in-the-steel-industry/, accessed in 04.07.2025.
**[9].** ***, https://www.tatasteel.com/newsroom/press-releases/india/2021/tata-steel-executes-the-inaugural-blockchain-enabled-trade-between-india-and-bangladesh/, accessed in 04.07.2025.
**[10].** ***, https://www.tatasteeluk.com/corporate/news/demonstrating-the-potential-of-blockchain, accessed in 04.07.2025.
**[11].** ***, https://www.unlock-bc.com/80772/uae-universal-tube-carries-out-second-blockchain-trade-transaction/, accessed in 04.07.2025.
**[12].** ***, https://www.koreatimes.co.kr/business/companies/20221201/posco-intl-introduces-blockchain-based-electronic-bills-of-lading, accessed in 04.07.2025.
**[13]. Osato Itohan Oriekhoe, *et al.***, *Blockchain in supply chain management: A review of efficiency, transparency, and innovation*, DOI: 10.30574/ijsra.2024.11.1.0028, 2024.
**[14]. Tomaž Kukman Sergej Gričar**, *Blockchain for Quality: Advancing Security, Efficiency, and Transparency in Financial Systems*, DOI: 10.3390/fintech4010007, 2025.
**[15]. Özgür Karaduman, Gülsena Gülhas**, *Blockchain-Enabled Supply Chain Management: A Review of Security, Traceability, and Data Integrity Amid the Evolving Systemic Demand*, DOI: 10.3390/app15095168, 2025.
**[16]. Aimin Yang, *et al.***, *Research on logistics supply chain of iron and steel enterprises based on block chain technology*, DOI: 10.1016/j.future.2019.07.008, 2019.
**[17].** ***, https://libertysteelgroup.com/ro/companie/viziune/, accessed in 16.07.2025.