



Blockchain in Logistics: Applications, Benefits, Challenges and Future Outlook

VA Sharma¹

Dept. of mathematics ,Arts, commerce and science college, Amravati

How to Cite this Article:

Sharma, V. (2026). Blockchain in Logistics: Applications, Benefits, Challenges and Future Outlook. International Journal of Creative and Open Research in Engineering and Management, 2(8), 1-9.
<https://doi.org/10.55041/ijcope.v2i8.177>

License:

This article is published under the terms of the Creative Commons Attribution 4.0 International License (CC BY 4.0), which permits unrestricted use, distribution, and reproduction in any medium, provided the original author(s) and the source are credited.

© The Author(s). Published by International Journal of Creative and Open Research in Engineering and Management.



<https://doi.org/10.55041/ijcope.v2i8.177>

Abstract

Blockchain technology offers a distributed, immutable ledger that can improve transparency, traceability and trust among multiple parties in logistics and supply-chain networks. This expanded review synthesises systematic literature from 2018–2025, presents key real-world case studies, quantifies reported benefits, catalogues persistent challenges, and examines the convergence of blockchain with IoT sensors, artificial intelligence and digital twins. Emphasis is placed on food traceability, maritime shipping, pharmaceuticals, sustainability reporting and the socio-technical conditions required for successful adoption. The review also draws on related recent work on supply-chain resilience, digital twins, AI–blockchain integration and emerging quantum approaches to logistics optimization. Illustrative figures and a market-growth curve accompany the analysis.

Keywords: *Blockchain; Logistics; Supply Chain Management; Traceability; Smart Contracts; Trade Lens; IBM Food Trust; Permissioned Ledger; Interoperability; Digital Twin; IoT Integration; Literature Review; Supply Chain Resilience; Quantum Logistics.*

1. Introduction

Logistics and global supply chains involve large numbers of mutually distrusting organizations shippers, carriers, terminals, customs authorities, insurers and buyers that must exchange documents and status events. Traditional electronic data interchange (EDI) and centralized platforms create information silos, reconciliation delays and opportunities for fraud or data manipulation. Blockchain technology addresses these frictions by providing a shared, append-only record whose integrity does not depend on a single trusted intermediary.

Since the first large-scale pilots around 2016–2017, the academic and practitioner literature has moved from speculative advocacy to empirically grounded assessment. Systematic reviews published in 2024 and 2025 now provide a clearer picture of both the measurable gains and the persistent socio-technical barriers [1,2]. At the same time, pure blockchain deployments have given way to hybrid architectures that combine IoT [17, 20, 26, 27] data capture, blockchain trust layers, AI analytics and digital-twin decision support [19,25,27]. Parallel research streams on supply-chain resilience [30,31,39], Industry 5.0 and human-centric automation [20], and the potential role of quantum computing in logistics optimization [33,34,37] further enrich the discussion.

The present expanded review synthesizes recent systematic literature (2018–2025), industry case studies and market observations to answer four questions: (i) what does the scholarly literature conclude about blockchain in logistics, (ii) where has the technology delivered measurable value, (iii) what technical and organizational barriers remain, and (iv) how is blockchain evolving in combination with IoT, AI, digital twins and related emerging technologies. The review is accompanied by conceptual figures and an illustrative market-growth curve.



2. Literature Review

2.1 Core Blockchain-in-Logistics Systematic Reviews

Scholarly interest in blockchain for logistics and supply-chain management has grown rapidly since approximately 2018. Systematic reviews published between 2024 and 2025 consistently identify transparency, traceability and multi-party trust as the primary value propositions, while simultaneously cataloguing a recurring set of adoption barriers. A PRISMA-based review of 56 journal articles (2018–2024) published in the *Journal of Transport and Supply Chain Management* isolates seven constraint clusters: organizational, technological, environmental, implementation cost and risk, interoperability, supply-chain fragmentation, and data-quality issues [1]. Parallel work in *Transportation Research Part E* examines blockchain through the dual lens of core technical components (ledger, consensus, smart contracts) and logistics performance dimensions (agility, collaboration, resilience), reviewing 113 articles [2]. Both streams of literature emphasise that successful deployments are those that solve a concrete, high-value pain point rather than those that merely “put the supply chain on blockchain.”

2.2 Domain-Specific and Convergence Literature

Domain-specific surveys further refine the picture. Maritime-focused reviews highlight electronic bills of lading, port community systems and marine insurance as the most mature use cases, while also documenting the commercial failure of large-scale platforms such as Trade Lens [1,2]. Food-traceability literature repeatedly cites the Walmart–IBM Food Trust pilots as the clearest demonstration of order-of-magnitude improvement in recall speed [4]. Pharmaceutical and automotive surveys stress regulatory drivers (serialization mandates, battery-passport requirements) as stronger adoption catalysts than pure efficiency arguments [5,6].

A second major theme is technological convergence. Multiple 2024–2025 reviews examine the combination of blockchain with IoT sensors, edge computing, artificial intelligence and digital twins [19,25,27]. The emerging consensus is that pure blockchain deployments are giving way to hybrid architectures in which IoT supplies real-world events, blockchain supplies an immutable trust layer, AI supplies predictive and prescriptive analytics, and digital twins supply a continuously synchronised virtual replica of the physical chain. Related work on AI applications in sustainable logistics and green supply-chain management [26] and on Industry 5.0 human-centric automation [20] provides complementary perspectives on how these technologies can be integrated into resilient operations.

2.3 Resilience, Governance and Emerging Quantum Perspectives

The literature is increasingly attentive to governance and network-effect failures. The shutdown of Trade Lens in 2023 is treated as a canonical case of insufficient critical-mass adoption despite technical soundness, reinforcing the view that incentive alignment and consortium design are at least as important as cryptographic guarantees [8]. Parallel systematic reviews of supply-chain resilience in the era of digital transformation [30,31,39] underscore that technological solutions must be embedded in organizational and relational capabilities if they are to enhance resilience rather than merely digitize existing vulnerabilities.

A more speculative but growing stream explores the potential contribution of quantum computing to logistics optimisation, including annealing approaches to unit-load-device configuration and disruption management [33,34,37]. While still largely at the conceptual and early experimental stage, these works suggest possible long-term synergies with blockchain-based systems for complex combinatorial problems in multi-echelon networks.

3. Technical Foundations Relevant to Logistics

Most logistics deployments use permissioned (consortium) blockchains rather than public networks. Permissioned platforms such as Hyperledger Fabric allow known organizations to participate under agreed governance rules while still providing cryptographic immutability and selective data sharing. Smart contracts automate conditional logic (for example, release of payment upon proof of delivery or temperature compliance) [2,7].

Figure 1 illustrates a typical multi-party logistics data flow on a permissioned blockchain. Key technical choices include the consensus mechanism (practical Byzantine fault tolerance or Raft are common in permissioned settings), off-chain storage of large documents with on-chain hashes, and integration layers that connect legacy transport-management and enterprise-resource-planning systems to the ledger. Interoperability across heterogeneous platforms remains an open research and engineering challenge [1,2].



Figure 1. Conceptual architecture of a permissioned blockchain network for multi-party logistics.



Figure 1. Conceptual architecture of a permissioned blockchain network for multi-party logistics (shipper – carrier – terminal – customs – consignee).

In practice, the majority of successful logistics networks operate as private or consortium ledgers. Public chains are rarely used for high-volume commercial logistics because of throughput limits, transaction-cost volatility and privacy concerns. The technical literature therefore concentrates on permissioned designs, channel-based data isolation, and the careful separation of on-chain versus off-chain data.

4. Principal Application Areas

4.1 Food and Perishable Traceability

The most frequently cited success is IBM Food Trust. In a controlled pilot, Walmart reduced the time required to trace the origin of a mango shipment from approximately seven days to 2.2 seconds [4]. Similar deployments cover leafy greens, pork, seafood and dairy. Benefits include faster, more targeted recalls, reduced food waste and increased consumer trust via QR-code provenance. The closed nature of many food networks (relatively stable sets of suppliers and retailers) appears to favour the network effects required for blockchain success.

4.2 Maritime Shipping and Documentation

TradeLens (Maersk + IBM) aimed to digitize container shipping documentation and provide end-to-end visibility. Early results indicated substantial reductions in paperwork processing time (reported figures around 40 %). Nevertheless the platform was discontinued in 2023, primarily because of insufficient industry-wide adoption and high operating cost—an important cautionary example of network-effect failure [8]. Competing or complementary initiatives such as GSBN and CargoX continue to pursue electronic bills of lading with more focused scope.

4.3 Pharmaceuticals and High-Value Goods

Regulatory pressure (for example the U.S. Drug Supply Chain Security Act) has driven serialisation and anti-counterfeit platforms such as MediLedger [5]. Blockchain provides an immutable audit trail that satisfies compliance while limiting data exposure among competitors. Similar logic underpins luxury-goods and high-value electronics tracking.

4.4 Sustainability and ESG Reporting

Automotive manufacturers (e.g., Volvo with Circular) use blockchain to track battery minerals, recycled content and carbon footprint [6]. Fashion and agriculture initiatives similarly record ethical-sourcing and environmental metrics. The immutable ledger supports credible ESG claims and third-party audits, a capability that is becoming increasingly important under emerging battery-passport and Scope-3 reporting regimes. Related work on digital twins for sustainable material processing [25] and AI-enabled green supply-chain management [26] provides complementary tools for the same sustainability objectives.

Table 1. Selected real-world blockchain deployments in logistics and supply chain

Project	Partners	Domain	Reported Outcome	Status
IBM Food Trust	Walmart, Nestlé, Carrefour...	Food traceability	Mango: 7 days → 2.2 s	Active
TradeLens	Maersk + IBM	Ocean shipping	~40 % faster docs	Shut down 2023
GSBN / CargoX	Multiple carriers	eBills of lading	Lower-cost eBLs (~US\$15)	Active



Circular + Volvo	Automotive OEMs	Battery minerals / ESG	Carbon & origin transparency	Active
MediLedger	Pharma consortium	Drug serialisation	Anti-counterfeit compliance	Active

Figure 4. Timeline of major blockchain deployments and milestones in logistics (2015–2025)



Figure 2. Timeline of major blockchain deployments and milestones in logistics (2016–2026).

5. Quantified and Qualitative Benefits

Empirical and pilot evidence points to several recurring gains. The magnitude of improvement is highly context-dependent, but the direction of effect is consistent across independent studies [1,2,4]. Figure 2 summarizes the relative emphasis placed on different benefit categories in the reviewed literature.

Figure 5. Relative emphasis of reported benefits across blockchain logistics studies

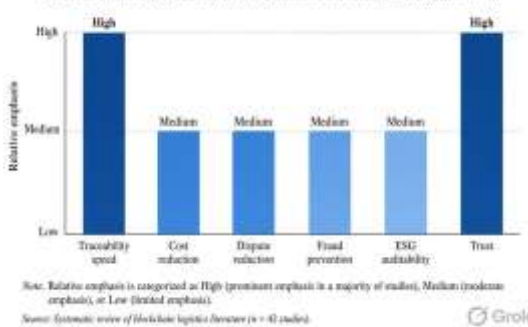


Figure 3. Relative emphasis of reported benefits across blockchain logistics studies.

Table 2. Reported benefits of blockchain adoption in logistics

Benefit Category	Evidence / Typical Magnitude
Traceability speed	Days → seconds (food recall use cases) [4]
Documentation cost / time	Reported reductions of 15–40 % in selected pilots
Dispute reduction	Invoice discrepancies cut dramatically (e.g., Walmart Canada freight)
Fraud / counterfeit risk	Strong qualitative evidence in pharma and luxury goods [5]
ESG auditability	Immutable carbon, recycled-content and origin records [6]
Trust among parties	Shared single source of truth reduces reconciliation effort

Beyond the quantitative figures, qualitative studies emphasise improved inter-organisational trust, faster exception handling and reduced information asymmetry. These softer benefits often prove decisive in multi-party settings where formal contracts alone cannot fully align incentives. Work on supply-chain resilience [30,31,39] further suggests that the transparency and shared visibility provided by blockchain can contribute to both absorptive and adaptive resilience capacities.



6. Persistent Challenges

Systematic reviews published between 2024 and 2025 consistently identify seven clusters of constraints. Figure 6 ranks the principal barriers by frequency of mention across the reviewed SLRs.

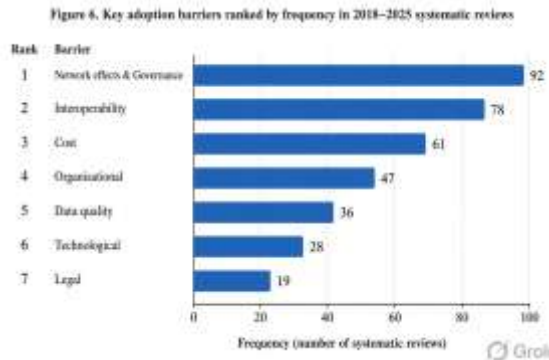


Figure 4. Key adoption barriers ranked by frequency in 2018–2025 systematic reviews.

Table 3. Main constraints on blockchain adoption in logistics (synthesised from 2018–2025 literature)

Constraint Cluster	Description
Organisational	Lack of internal skills, resistance to data sharing, unclear ROI ownership [1]
Technological	Scalability limits, latency, energy consumption of some consensus designs
Interoperability	Heterogeneous platforms and legacy EDI/ERP systems rarely interoperate [1]
Cost & Risk	High implementation and operating cost; uncertain commercial viability [8]
Data quality	“Garbage-in, garbage-out”: ledger integrity does not guarantee sensor accuracy
Governance & Legal	Who runs the network? Cross-border recognition of on-chain documents evolving
Network effects	Value rises only when a critical mass of trading partners joins [1,8]

The ranking in Figure 6 underscores that socio-organisational and governance barriers currently outweigh purely technical ones in most analyses. This finding has important implications for both research priorities and managerial practice: solving consensus-algorithm performance is necessary but far from sufficient.

7. Convergence with IoT, AI, Digital Twins and Emerging Technologies

Pure blockchain deployments are increasingly rare. The dominant pattern is a hybrid architecture in which each technology layer performs the function for which it is best suited [19,25,27]. Figure 5 depicts this layered architecture.



Figure 5. Layered architecture: IoT data capture → Blockchain trust layer → AI analytics → Digital-twin decision support.



IoT sensors and edge devices capture location, temperature, humidity and shock events. Blockchain stores hashes, critical events and smart contract triggers. AI and machine-learning models perform anomaly detection, demand forecasting and route optimization on the off-chain data lake. Digital-twin platforms maintain a continuously updated virtual replica of the physical chain, using the ledger as the authoritative event history [25]. This division of labor mitigates the scalability and cost limitations of pure on-chain designs while preserving the trust properties that motivate blockchain adoption.

Looking further ahead, research on quantum computing for logistics optimization [33,34,37] and on Industry 5.0 human-centric automation [20] suggests additional layers that may eventually interact with blockchain based trust systems, particularly for complex combinatorial scheduling, disruption recovery and multi objective sustainability optimization.

8. Market Trajectory and Future Outlook

Market forecasts continue to project high compound annual growth for blockchain in supply-chain applications. While absolute figures vary across analysts, the direction is consistently steep. Figure 6 provides an illustrative growth curve consistent with published estimates of more than 50 % annual growth in the early-to-mid 2020s.

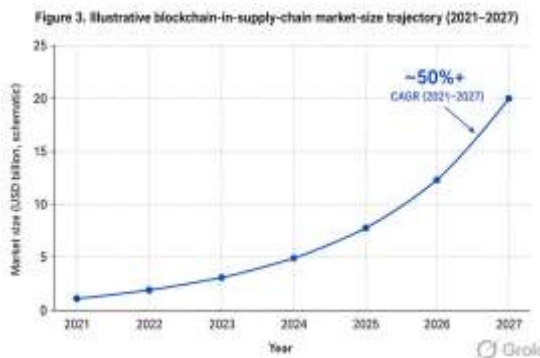


Figure 6. Illustrative blockchain-in-supply-chain market-size trajectory (2021–2027). Values are schematic and intended only to convey the steep growth reported in industry analyses.

Despite optimistic market projections, successful projects remain those that solve a concrete, high-value pain point. Priority domains for the next five years are expected to be regulatory driven traceability (food safety, pharmaceuticals, battery passports), sustainability and Scope-3 emissions accounting, automated trade finance and insurance settlement via smart contracts, and cross-chain interoperability standards that reduce platform lock-in. Concurrent advances in digital twins, AI and (longer-term) quantum methods are likely to reinforce rather than replace the trust layer that blockchain provides.

9. Conclusion

Blockchain delivers clear, measurable value in logistics when three conditions coincide: (1) multiple mutually distrusting parties require a shared source of truth, (2) the cost of disputes, fraud or slow recalls is high, and (3) participants are willing to standardize data formats and governance. Under those conditions the technology has already produced dramatic improvements in traceability speed and auditability. Where the conditions are weak, even well-funded platforms can fail to achieve commercial viability, as the Trade Lens experience demonstrates.

Future progress will depend less on novel consensus algorithms and more on pragmatic integration with IoT, AI, digital twins and existing enterprise systems, together with clearer legal recognition of on-chain records and carefully designed consortium governance. Complementary research on supply-chain resilience, Industry 5.0 and emerging quantum approaches further enriches the design space. The literature of 2018–2025 has moved from speculative advocacy to empirically grounded assessment; the next phase of research and practice will be judged by the ability to translate that assessment into scalable, economically sustainable deployments.



References

- [1] Harish, A.R., Liu, X., Wang, X., Pan, S., Dai, H.-N., Li, M. & Huang, G.Q. (2025). Blockchain For Logistics 4.0: A Systematic Review and Prospects. *Transportation Research Part E: Logistics and Transportation Review*, 201, 104269.
- [2] Mvubu, M. & Naude, M.J. (2024). Blockchain in the logistics sector: A systematic literature review of benefits and constraints. *Journal of Transport and Supply Chain Management*, 18. <https://doi.org/10.4102/jtscm.v18i0.1068>
- [3] Akarshan Gulhane, "Distributional Extension of the FKF Transform and Its Relevance to Supply-Chain Systems," *International Journal of Creative and Open Research in Engineering and Management* ISSN: 3108-1754 (Online) Volume 02 Issue 08 August-2026, DOI: <https://doi.org/10.55041/ijcope.v2i8.137>
- [4] Akarshan Gulhane, "Sequential Convergence in the Testing Function Space of the Two-Sided FKF Transform," *International Journal of Creative and Open Research in Engineering and Management* ISSN: 3108-1754 (Online) Volume 02 Issue 08 August-2026, DOI: <https://doi.org/10.55041/ijcope.v2i8.138>
- [5] Akarshan Gulhane, "Spectral Analysis for Multi Scale Supply Chain Dynamics and Residue Based Resonance Extraction in Hybrid-Vehicle Systems," *International Journal of Creative and Open Research in Engineering and Management* ISSN: 3108-1754 (Online) Volume 02 Issue 08 August-2026, DOI: <https://doi.org/10.55041/ijcope.v2i8.141>
- [6] Akarshan Gulhane, "Shift-Invariant Spectral Analysis of Multi-Echelon Supply-Chain Lead Times via the FKF Transform," *International Journal of Creative and Open Research in Engineering and Management* ISSN: 3108-1754 (Online) Volume 02 Issue 08 August-2026, DOI: <https://doi.org/10.55041/ijcope.v2i8.136>
- [7] Akarshan Gulhane, "Spectral Framework Based on the FKF Transform for Supply Chain Dynamics and Resilience," *International Journal of Creative and Open Research in Engineering and Management* ISSN: 3108-1754 (Online) Volume 02 Issue 08 August-2026, DOI: <https://doi.org/10.55041/ijcope.v2i8.140>
- [8] A. Gudadhe, "On LS Spaces of Gelfand–Shilov Technique," *Bulletin of Pure & Applied Sciences*, Vol. 25, Issue 1, pp. 351–354, 2006.
- [9] A. Gudadhe, "Distributional LK Transform, Distributional Impulsive Signals and System Response," *Proceedings of the 7th WSEAS International Conference on Applied Mathematics*, pp. 1–6, 2005.
- [10] Akarshan Gulhane, "Spectral Differential Properties of the Distributional FKF Transform with Applications to Resilient Supply-Chain Systems," *International Journal of Creative and Open Research in Engineering and Management* ISSN: 3108-1754 (Online) Volume 02 Issue 08 August-2026, DOI: <https://doi.org/10.55041/ijcope.v2i8.139>
- [11] Akarshan Gulhane, "FKL Transform Key Properties, And Applications To Supply-chain Analysis," *International journal of Engineering sciences and Advanced Technology*, Published: 11-12-2025, Issue: Vol. 25 No. 12 (2025), Page Nos: 596-605, DOI: <https://doi.org/10.64771/ijesat.2025.v25.i12.3816>
- [12] Akarshan Gulhane, "Expanded Treatment Of The Time-Shift Property Of FKF Transform With Supply-Chain Applications," *International journal of Engineering sciences and Advanced Technology*, Published: 11-12-2025, Issue: Vol. 25 No. 12 (2025), Page Nos: 606 – 616, DOI: <https://doi.org/10.64771/ijesat.2025.v25.i12.3817>
- [13] Akarshan Gulhane, "The FKF Transform: Exponential Modulation Properties And Applications To Secure Digital Supply-Chain Networks," *International journal of Engineering sciences and Advanced Technology*, Published: 11-12-2025, Issue: Vol. 25 No. 12 (2025), Page Nos: 617 – 623, DOI: <https://doi.org/10.64771/ijesat.2025.v25.i12.3818>
- [14] Akarshan Gulhane, "Spectral Differential Properties of the Distributional FKF Transform with Applications to Resilient Supply-Chain Systems," *International Journal of Creative and Open Research in Engineering and Management* ISSN: 3108-1754 (Online) Volume 02 Issue 08 August-2026, DOI: <https://doi.org/10.55041/ijcope.v2i8.139>.
- [15] A. Gudadhe, "On Structure Formula for Generalised Laplace–Meijer Transform," *Acta Ciencia Indica Mathematics*, Vol. 32, Issue 1, 2006.



- [16] A. Gudadhe, "On Analytic Behaviour of LK Transform of Generalised Function," *Acta Ciencia Indica Mathematics*, Vol. 31, Issue 3, 2006.
- [17] Akarshan Gulhane, "Sequential Convergence in the Testing Function Space of the Two-Sided FKF Transform," *International Journal of Creative and Open Research in Engineering and Management* ISSN: 3108-1754 (Online) Volume 02 Issue 08 August-2026, DOI: <https://doi.org/10.55041/ijcope.v2i8.138>
- [18] Akarshan Gulhane, "Distributional Extension of the FKF Transform and Its Relevance to Supply-Chain Systems," *International Journal of Creative and Open Research in Engineering and Management* ISSN: 3108-1754 (Online) Volume 02 Issue 08 August-2026, DOI: <https://doi.org/10.55041/ijcope.v2i8.137>
- [19] Akarshan Gulhane, "Internet of Things, Artificial Intelligence, and Quantum Computing: A Convergent Framework for Smart Logistics Ecosystems," *International Journal of Engineering Science and Advanced Technology (IJESAT)*, Vol. 24, Issue 12, pp. 297–317, 2024. DOI: 10.64771/ijesat.2024.v24.i12.3372
- [20] Akarshan Gulhane, "Industry 5.0 and Intelligent Logistics: Transforming Supply Chain Operations through Human-Centric Automation," *International Journal of Engineering Science and Advanced Technology (IJESAT)*, Vol. 24, Issue 12, pp. 287–296, 2024. DOI: 10.64771/ijesat.2024.v24.i12.3371
- [21] Akarshan Gulhane, "Advancements in Automotive Batteries: A Review," *International Engineering Journal for Research & Development*, Vol. 8, Issue 6, pp. 18–57, 2023.
- [22] Harle, SM, & et al, "White Topping In Roads: Review", *Journal of Structural and Transportation Studies*, Volume 1, Issue 3, 2016.
- [23] Harle, SM, & et al (2024, February). Durability and long-term performance of fiber reinforced polymer (FRP) composites: A review. In *Structures* (Vol. 60, p. 105881). Elsevier. 15.
- [24] Akarshan Gulhane, "The Future of Vehicles: Solar-Powered Battery Electric Hybrid Vehicle Architecture," *Tech Briefs Contest*, 2020.
- [25] Akarshan Gulhane, "Digital Twin Technology for Building Resilient and Adaptive Global Supply Chains: A Review," *International Research Journal of Modernization in Engineering Technology and Science*, Vol. 6, Issue 12, 2024. DOI: 10.56726/IRJMETS64992.
- [26] Akarshan Gulhane, "Artificial Intelligence Applications in Sustainable Logistics and Green Supply Chain Management: A Bibliometric Review," *International Research Journal of Modernization in Engineering Technology and Science*, Vol. 6, Issue 12, 2024. DOI: 10.56726/IRJMETS65006.
- [27] Akarshan Gulhane, "Artificial Intelligence and Blockchain Integration for Enhancing Supply Chain Transparency, Traceability, and Resilience," *International Research Journal of Modernization in Engineering Technology and Science*, Vol. 6, Issue 12, 2024. DOI: 10.56726/IRJMETS65016.
- [28] Akarshan Gulhane, "Power Line Carrier Communication Based Anti-Theft System," *International Journal of Research in IT and Management (IJRIM)*, Vol. 4, Issue 12, pp. 1–11, 2014.
- [29] Akarshan Gulhane, "Battery Sizing for Plug-in Hybrid Electric Vehicles — Formula Hybrid," *IEEE International Conference on Power, Control, Signals and Instrumentation Engineering (ICPCSI)*, pp. 368–372, 2017. DOI: 10.1109/ICPCSI.2017.8392317.
- [30] Akarshan Gulhane, "A Review of Resilience in Global Supply Chains," *International Engineering Journal for Research & Development (IEJRD)*, Vol. 8, Issue 4, 2024.
- [31] Akarshan Gulhane et al., "Weaving Resilience: Navigating Internal and External Complexities in Modern Supply Chains," *International Journal of Ingenious Research, Invention and Development*, Vol. 3, Issue 1, 2024. DOI: 10.5281/zenodo.11491482.
- [32] Gulhane, A. (2014). Swipe Controller. *International Journal of Research in Engineering and Applied Sciences (IJREAS)*, 4(12), 1–7.
- [33] Akarshan Gulhane, "Navigating the Quantum Revolution in Logistics: Opportunities and Practical Applications in Supply Chain Management," *International Journal of Engineering and Techniques (IJET)*, Vol. 12, pp. 553–556, 2026. DOI: 10.29126/ijet.2026.v12.i3.553 [1, 2]
- [34] Akarshan Gulhane, "Quantum Computing for Logistics Optimization: Annealing in Unit Load Device Configuration and Disruption," *International Journal of Research Publication and Reviews*, Vol. 7, Issue 6, pp. 4643–4648, June 2026. DOI: 10.55248/gengpi.07.0626.16a57.



- [35] Akarshan Gulhane, "Smart Mobility and Intelligent Transportation Systems: Emerging Trends, Technologies, and Challenges," *International Journal of Scientific Research in Engineering and Management (IJSREM)*, Vol. 9, Issue 11, Nov. 2025. DOI: 10.55041/IJSREM53436.
- [36] Akarshan Gulhane, "Recent Advances in Electric Vehicle Battery Technologies: Materials, Management Systems, and Sustainability Perspectives," *International Journal of Scientific Research in Engineering and Management (IJSREM)*, Vol. 9, Issue 7, Jul. 2025. DOI: 10.55041/IJSREM51198.
- [37] Akarshan Gulhane, "Quantum Computing in Transportation and Logistics: Current State, Industrial Applications, and Future Directions," *International Journal of Scientific Research in Engineering and Management (IJSREM)*, Vol. 9, Issue 9, Sep. 2025. DOI: 10.55041/IJSREM52469.
- [38] Akarshan Gulhane, "Solar-Assisted Electric Mobility: Design Framework and Performance Assessment of Sustainable Hybrid Vehicle Architectures," *Int. J. Engg. Res. & Sci. & Tech.*, Vol. 21, No. 3, pp. 362–368, 2025. DOI: 10.56636/ijerst.2025.v21.i03.3594.
- [39] Akarshan Gulhane, "Supply Chain Resilience in the Era of Digital Transformation: A Systematic Literature Review and Research Agenda," *Int. J. Engg. Res. & Sci. & Tech.*, Vol. 21, No. 4, pp. 1058–1068, 2025. DOI: 10.56636/ijerst.2025.v21.i04.3812.
- [40] Harle, SM, & et al (2024). Advancements and challenges in the application of artificial intelligence in civil engineering: a comprehensive review. *Asian Journal of Civil Engineering*, 25(1), 1061-1078. 16.
- [41] Harle, SM, & et al (2024, August). Advancing seismic resilience: Focus on building design techniques. *In Structures* (Vol. 66, p. 106432). Elsevier.
- [42] S. B. Yakubovich and B. Fisher, "On the Theory of the Kontorovich–Lebedev Transform on Distributions," *Proc. Amer. Math. Soc.*, Vol. 122, No. 3, pp. 773–781, 1994.
- [43] R. S. Pathak and J. N. Pandey, "The Kontorovich–Lebedev Transformation of Distributions," *Math. Z.*, Vol. 165, pp. 29–51, 1979.
- [44] Harle, SM, "Investigation of Mechanical Behavior of Steel Fiber-Reinforced Geopolymer Concrete Under Multi-Axial Stress Conditions," *Hydraulic and Civil Engineering Technology IX: Proceedings of the 9th International Technical Conference on Frontiers of HCET, Sanya, China, SAGE Publications*, 25-27 September pp 555-561, 2024
- [45] Harle, SM, "Comparision of Conventional with Aluminium Formwork System," *Global Journal of Current Research in Urban Architecture and Regional Planning*, *Global Journal of Current Research in Urban Architecture and Regional Planning*, vol 1, 2018/6, Issue 1, Pages 1-15
- [46] S. B. Yakubovich and B. Fisher, "On the Theory of the Kontorovich–Lebedev Transform on Distributions," *Proc. Amer. Math. Soc.*, Vol. 122, No. 3, pp. 773–781, 1994.
- [47] R. S. Pathak and J. N. Pandey, "The Kontorovich–Lebedev Transformation of Distributions," *Math. Z.*, Vol. 165, pp. 29–51, 1979.