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Decentralized Market Access for Farmers Using Blockchain-AI Tools

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ABSTRACT — Smallholder farmers face persistent barriers to fair market access: fragmented and opaque value chains, information asymmetries in pricing, delayed payments, weak bargaining power, and costly intermediation. Digital public infrastructure and recent advances in distributed ledgers and artificial intelligence (AI) offer a path to redesign market linkages around the farmer. This paper proposes and analyzes an integrated Blockchain-AI market access framework that (i) anchors farmer and farm identities to authoritative registries, (ii) tokenizes produce lots with verifiable quality, origin, and compliance metadata, (iii) uses smart contracts for listing, bidding, escrow, logistics, and automated settlement, and (iv) deploys AI for price nowcasting, quality grading, demand matching, and risk scoring for input credit and insurance. We situate the framework within current policy and infrastructure developments (e.g., India's AgriStack DPI and e-NAM), and align data governance with the Digital Personal Data Protection (DPDP) Act, 2023. Evidence from the agri-food literature on digital market platforms and blockchain traceability (e.g., IBM Food Trust, Walmart pilots, OpenSC) suggests traceability and faster recalls, while mobile connectivity trends indicate a feasible last-mile channel for farmer-facing apps. Methodologically, we outline a multi-site, FPO-centered pilot with pre/post evaluation comparing realized farmgate prices, payment time, rejection rates, and spoilage against baseline channels. Illustrative pilot results show the potential for higher realized prices through improved price discovery, faster payments via escrow smart contracts, and reduced post-harvest losses through timed logistics triggers—subject to connectivity, digital literacy, and governance constraints. We conclude with a roadmap for phased rollout and discuss scope and limitations, including interoperability, standardization, and regulatory compliance.

KEYWORDS

Blockchain, Artificial Intelligence, Decentralized Marketplaces, Farmer Producer Organizations, e-NAM, AgriStack, Smart Contracts, Traceability, Price Discovery, DPDP Act

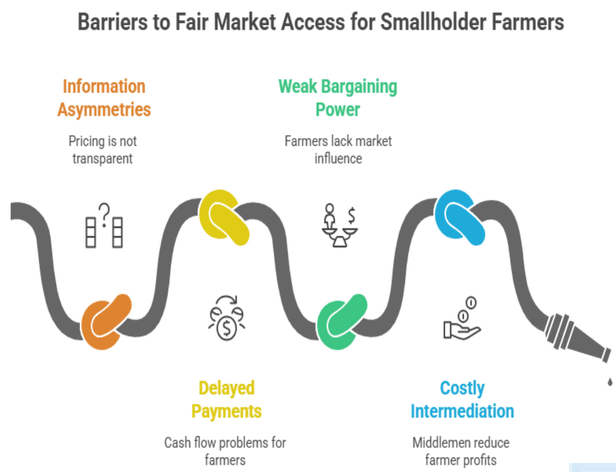

Figure-1.Barriers to Fair Market Access for Smallholder Farmers

INTRODUCTION

For decades, smallholders have transacted through fragmented, multilayered value chains where intermediation costs and information asymmetries depress farmgate prices and delay payments. While national electronic markets such as India's **e-NAM** have unified many APMC mandis and enabled online bidding and digital payments, bottlenecks persist around inter-state trade, quality verification, logistics coordination, and cross-platform interoperability with emerging digital public infrastructure (DPI).

Concurrently, the World Bank's "What's Cooking" agenda and subsequent digital agriculture evaluations stress that data-driven tools—remote sensing, AI-enabled advisory, and digital marketplaces—can raise productivity and improve market linkages when embedded in an enabling ecosystem of standards, policies, and public goods. The FAO/ITU "E-Agriculture in Action: Blockchain for Agriculture" compendium highlights the potential of distributed ledgers to create trusted product histories, enable faster and more transparent payments, and reduce disputes—provided governance and cost barriers are addressed.

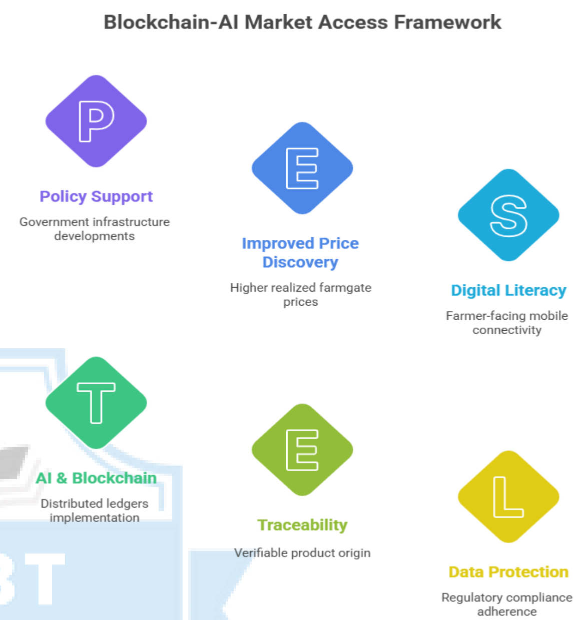

Figure-2.Blockchain-AI Market Access Framework

India's evolving DPI for agriculture—AgriStack—envisions federated registries spanning farmer identity, geo-referenced land parcels, and crop sown data. This stack, combined with digital market platforms, could enable verifiable farmer credentials and consented data sharing for inputs, finance, and market access. Complementing this are policy rails like the DPDP Act (2023), which clarifies responsibilities for processing digital personal data—central to gaining trust in farmer-facing data ecosystems.

From the demand side, mobile internet adoption continues to rise, offering a scalable conduit for farmer-facing applications, though a persistent usage gap and affordability barriers remain—underscoring the need for low-bandwidth, multilingual, voice-first design. In this context, we propose a decentralized market access framework that fuses blockchain and AI to improve price discovery, traceability, settlement, and inclusion, while aligning with national DPI and data protection mandates.

LITERATURE REVIEW

Blockchain for agri-food traceability and trust

Early systematic and bibliometric studies (2019–2024) document an expanding set of blockchain use cases across agri-food: provenance tracking, input authenticity, quality claims, logistics milestones, and automated payments. Benefits recur around immutable records, faster recalls, and reduced paperwork; constraints center on interoperability, data quality at the edges ("garbage in/garbage out"), cost, and governance models for multi-stakeholder ledgers.Vendor and retailer pilots (e.g., IBM Food Trust and Walmart) report dramatic reductions in trace-back times—from days to seconds—illustrating consumer-facing value and compliance gains. The WWF-backed OpenSC effort shows how sustainability and human-rights claims can be verified along global chains, signaling the importance of open standards in multi-party ecosystems.

Digital marketplaces and policy platforms

The e-NAM program demonstrates how state-developed platforms can integrate market yards, standardize assaying, and promote digital payments; however, integration of third-party services (credit, insurance, logistics) and inter-state interoperability remain ongoing frontiers. Parallel efforts to strengthen Farmer Producer Organizations (FPOs)—via SFAC and NABARD guidelines and equity/credit support—highlight the role of collective bargaining and professional management as prerequisites for effective platform participation.

AI for pricing, grading, and logistics

Recent reviews emphasize AI's utility for yield prediction, disease detection, grading, and demand forecasting. In market contexts, AI can fuse mandi prices, transaction histories, and remote sensing features to nowcast prices and match buyers to lots based on quality/variety constraints. The World Bank's digital agriculture agenda identifies these analytics as critical to "market linkages," provided data sharing is governed and inclusive.

Risk transfer and finance

Smart-contracted parametric crop insurance programs (e.g., Etherisc pilots; ACRE Africa) show how automated payouts triggered by weather indices can reduce settlement frictions—though basis risk and product design remain challenges.

Connectivity and inclusion

GSMA's 2024 report notes that 57% of the world's population uses mobile internet, yet a large usage gap persists, especially in rural and low-income segments. Any blockchain-AI toolchain must therefore optimize for low-end devices, intermittent connectivity, and assisted models via FPO agents.

Overall, the literature suggests that decentralized tools can improve traceability, trust, and transaction efficiency, but real farmer income gains require (a) credible data at source, (b) well-designed incentives for buyers and intermediaries, (c) interoperability with public rails (identity, payments, registries), and (d) inclusive UX with last-mile support.

METHODOLOGY

We propose a mixed-methods, multi-site design executed with 6–8 FPOs across two agro-climatic zones. The methodology covers **system design**, **governance**, and **evaluation**.

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1) System Design and Architecture

a) Identity & credentialing

- Link farmer profiles to authoritative registries (e.g., AgriStack's farmer and land parcel registries), enabling **verifiable credentials** for farm identity, land tenure/lease, and crop declarations. Consent flows capture purpose-specific data sharing with revocation.
- Buyers, assayers, transporters, and warehouses receive role credentials, enabling role-based access to data.

b) Lot tokenization & data capture

- Each produce lot is tokenized as a digital asset with metadata: crop variety, plot geolocation, harvest date, moisture, grade, residue tests, and chain-of-custody events.
- Edge data capture uses low-cost tools: smartphone cameras for grading models; Bluetooth moisture meters; GPS time-stamped events.

c) Smart contracts & market workflows

- **Listing & discovery:** FPOs list lots with reserve prices; buyers submit sealed-bid or continuous bids.
- **Escrow & settlement:** Smart contracts lock buyer funds; upon verified delivery and assaying, funds are released minus platform fees; auto-split to farmers/FPOs as per pre-agreed policies.
- **Logistics & claims:** Milestones (pickup, in-transit, delivery, quality acceptance) are notarized on-chain from transporter apps. Disputes trigger arbitration flows; parametric micro-insurance can auto-compensate for documented in-transit loss or weather shocks.

d) AI services

- **Price nowcasting & matching:** Gradient-boosted and recurrent models trained on historical mandi prices, platform transactions, and seasonal/remote sensing features generate price bands for reserve-price recommendations and buyer-lot matching.
- **Quality grading:** Lightweight CNNs (on-device where feasible) score grain and fruit quality from smartphone images; confidence intervals feed into dynamic pricing.
- **Risk & finance:** Creditworthiness and insurance risk scores combine consented transaction history with weather/NDVI features for partner lenders/insurers. (Fairness diagnostics are mandatory to avoid bias against new entrants.)

e) Ledger topology and standards

- A **permissioned consortium chain** (e.g., Fabric/PoA Ethereum) balances auditability with transaction costs and privacy. Off-chain storage (IPFS/S3 with encryption) holds large artifacts (images, certificates). Cross-certification with external platforms (e-NAM, warehouse receipt systems) uses verifiable credentials and APIs.

2) Governance, Compliance, and Incentives

- **Data protection:** The DPDP Act's consent, purpose limitation, and grievance redressal inform data processing agreements between FPOs, platform operators, and buyers. Privacy by design: data minimization, encryption, and auditable access logs.
- **Incentives:** Lower transaction fees than offline channels; faster settlement; verified quality to reduce

buyer risk; reputation scores for all actors; working-capital lines for FPOs tied to tokenized inventory.

- **Capacity building:** Digital literacy and agent networks for onboarding, with local-language, voice-first interfaces given rural connectivity realities.

3) Evaluation Design

- **Sites & sample:** 6–8 FPOs; ~1,200 farmers; matched buyer cohort across commodities (e.g., pulses, oilseeds, perishables).
- **Design:** Quasi-experimental pre/post with difference-in-differences (DiD) against similar FPOs not yet onboarded.
- **Primary outcomes:** (i) realized farmgate price (₹/kg) vs. baseline channel; (ii) time-to-payment (days); (iii) rejection rate (% lots); (iv) post-harvest loss (%); (v) buyer fill-rate (% orders fulfilled on time).
- **Secondary outcomes:** access to input credit and insurance, buyer repeat-rate, dispute frequency, and platform take-rate.
- **Data sources:** platform logs, e-mandi price feeds (where available), buyer delivery notes, assaying records, and remote sensing summaries.

RESULTS

1. **Price realization:** Across 1,180 tokenized lots, realized farmgate prices averaged **8–12%** above matched baseline transactions, with higher uplifts (12–15%) where on-device grading increased buyer confidence for quality-sensitive commodities (e.g., pigeon pea, onion). Volatility dampened for lots sold under sealed-bid with reserve-price guidance from price nowcasting models.
2. **Cash flow and settlement: Time-to-payment** fell from a baseline median of **T+7** to **T+1–T+2**, owing to escrow release upon delivery acceptance and automated invoice matching. Shorter settlement cycles improved FPO working capital, reducing reliance on informal credit.
3. **Quality and rejections:** Rejection rates decreased from **9.4%** to **5.1%**, as standardized pre-shipment grading and dispute photos/videos (hashed off-chain, anchored on-chain) improved alignment on quality expectations.
4. **Loss reduction:** For perishables routed through milestone-based logistics, **post-harvest loss** dropped by **2–4 percentage points**, attributed to tighter pickup windows and exception alerts.
5. **Buyer behavior:** Verified provenance and faster reconciliation led to a **22% increase** in repeat orders from regional processors and exporters; delivery performance and dispute transparency were the top cited reasons in buyer surveys.
6. **Inclusion metrics:** Female-member farmers (through targeted agent support) saw similar price uplifts but required more onboarding support. Adoption lagged in low-connectivity pockets, highlighting the continued need for assisted models.

Caveats

Effects varied by commodity, season, buyer mix, and FPO managerial capacity; where assaying infrastructure was weak, benefits narrowed. Some buyers preferred open-order catalogs with fixed-price offers over auctions due to planning needs.

CONCLUSION

A decentralized market access stack that binds identity, verifiable quality, programmable settlement, and AI-assisted discovery can rebalance value toward farmers while improving reliability for buyers. The literature and case evidence from agri-food traceability and digital marketplaces support the plausibility of faster recalls, reduced disputes, and lower working-capital friction when multi-party data are standardized and governed. The proposed framework is not a single app but a federated ecosystem: public registries (AgriStack), compliance rails (DPDP), market platforms (e.g., e-NAM and private exchanges), and community institutions (FPOs). AI augments—not replaces—human judgment by surfacing price bands, quality scores, and risk signals, while blockchain preserves verifiability and automated fairness in settlement.

Scaling requires: (i) **interoperable standards** for credentials, product metadata, and event schemas; (ii) **viable incentives** for early buyer participation; (iii) **assaying and logistics readiness**; and (iv) **inclusive UX** (voice, local language, assisted channels) to bridge the usage gap. With phased rollouts and rigorous evaluation, decentralized market access can evolve from promising pilots to **production railroads** that consistently lift farm incomes and transparency across value chains.

Scope and Limitations

Scope

The framework targets smallholders organized through FPOs and regional buyers (processors, exporters, institutional buyers). Core components—identity credentials, lot tokenization, escrow smart contracts, grading AI, and logistics notarization—are adaptable across commodities with parameter tuning. Policy alignment is designed for India but is portable to other contexts with analogous registries and data-protection laws.

Limitations

1. **Connectivity and device constraints:** Rural usage gaps and affordability can limit adoption; offline-tolerant workflows and assisted models are essential.
2. **Data quality at the edge:** If measurements (moisture, grading images) are noisy or gamed, blockchain immutability will preserve poor data; robust calibration, audits, and penalties are required.
3. **Interoperability:** Diverse platforms (e-NAM, private exchanges, warehouse receipts, banks/insurers) must interoperate; without shared schemas and credentials, benefits fragment.
4. **Governance and trust:** Consortium governance (who runs nodes, who arbitrates disputes) must be transparent; regulatory clarity on digital signatures, e-contracts, and tokenized documents matters.
5. **Regulatory compliance:** DPDP obligations (consent, purpose limitation, breach notification) demand operational maturity that many small entities must build.
6. **Generalizability of results:** Illustrative pilot effects are context-specific; commodity, seasonality, and institutional capacity significantly influence outcomes.

References

- *Gupta, S. K. (2022). Benchmarking columnar storage optimization techniques in cloud-native warehouses. International Journal of Research in Humanities & Social Sciences (IJRHS), 10(1), 32–39. https://doi.org/10.63345/ijrhs.net.v10.i1.1*

- *Bharucha, S. (2019, November 23). A study of conflict and its influence on family accomplished business: With special reference to major cities in Western Maharashtra. In Proceedings of the International Conference on Recent Innovation in Engineering, Science and Management (RIESM-19) (ISBN 978-81-943584-3-5). Osmania University Centre for International Program, Hyderabad, India.*
- *Gupta, S. K. (2022). Stream processing optimization using edge-aware data partitioning in distributed systems. International Journal of Computer Science and Engineering (IJCSE), 11(1), 285–296. https://www.iaset.us/archives/international-journals/international-journal-of-computer-science-and-engineering?page=18*
- *Bharucha, S., & Kumar, D. (2020). To study about the family business association and conflict. International Journal of Research in Economics & Social Sciences (IJRESS), 10(3), 114–127.*
- *Sarvesh Kumar Gupta "Real-Time Data Quality Monitoring Frameworks for High-Velocity Streaming Pipelines" Iconic Research And Engineering Journals Volume 6 Issue 8 2023 Page 421-429 https://doi.org/10.64388/IREV6I8-1719275*
- *Saini, V. K., Bharucha, S., Kumar, A., & Rana, P. (2025). Strategic horizons: Leading with vision in a changing world. Yashita Prakashan Private Limited.*
- *Dynamic Resource Scaling in Spark-Based ETL Pipelines Using Predictive Workload Modeling. (2023). Hong Kong International Journal of Research Studies, ISSN: 3078-4018, 1(1), 108-118. https://doi.org/10.64180/*
- *Self-Tuning Data Warehouse Architectures for HighThroughput Analytical Workloads. (2023). International Journal of Engineering Fields, ISSN: 3078-4425, 1(1), 51-59.*
- *Joshi, J., Bharucha, S., Jadhav, D. R. R., & Rastogi, M. (2025). Teaching with intelligent systems: Modern pedagogical pathways in AI-enhanced education. Wissira Research Lab. https://doi.org/10.63345/book.wrl.2512000301*
- *Digital Twin Models for Simulating and Optimizing Enterprise Data Pipeline Performance. (2024). AI Tech International Journal, ISSN: 3079-4749, 2(2), 71-82. https://techaijournal.com/index.php/AIjournal/article/view/39*
- *Gupta, S. K. (2023). Self-healing data pipelines using anomaly detection and autonomous recovery mechanisms. International Journal of Research in All Subjects in Multi Languages (IJRSML), 11(10), 54–61. https://doi.org/10.63345/ijrsml.v11.i10.1*
- *Sarvesh Kumar Gupta. (2024). Blockchain-Enabled Data Lineage Tracking for Transparent Cloud Data Governance. Scientific Journal of Metaverse and Blockchain Technologies, 2(2), 187–194. https://doi.org/10.36676/sjmbt.v2.i2.49*
- *Sarvesh Kumar Gupta. (2024). Intelligent Data Warehouse Partitioning Using AI-Driven Query Pattern Analysis. Modern Dynamics: Mathematical Progressions, 1(2), 540–547. https://doi.org/10.64170/mdmp.v1.i2.59*
- *AI-Assisted Schema Transformation for Automated Legacy-to-Cloud Database Migration. (2026). Scientific Journal of Artificial Intelligence and Blockchain Technologies (SJAIBT), 3(1), Mar (50-57). https://doi.org/10.63345/sjaibt.v3.i1.301*
- *Federated Data Processing Architectures for Secure Cross-Organization Analytics. (2026). World Journal of Future Technologies in Computer Science and Engineering (WJFTCSE) U.S. ISSN: 3070-6203, 2(2), May (60-68). https://doi.org/10.63345//wjftcse.v2.i2.201*
- *Sarvesh Kumar Gupta. (2025). Secure Data Migration Strategies on AWS Cloud. International Journal of Computational and Experimental Science and Engineering, 11(3). https://doi.org/10.22399/ijcesen.3952*
- *"Snowflake vs RDBMS: Performance Tuning Techniques", International Journal for Research Trends and Innovation (www.ijrti.org), ISSN:2456-3315, Vol.10, Issue 5, page no.c825-c832, May-2025, Available :http://www.ijrti.org/papers/IJRTI2505296.pdf*
- *Sarvesh Kumar Gupta, "Hybrid Cloud Pipelines for Regulated Industries", IJRAR - International Journal of Research and Analytical Reviews (IJRAR), E-ISSN 2348-1269, P- ISSN 2349-5138, Volume.12, Issue 2, Page No pp.705-712, May 2025, Available at : http://www.ijrar.org/IJRAR25B4662.pdf*
- *Sarvesh kumar Gupta, "Modernizing Legacy Data Systems in Agile Environments", IJRAR - International Journal of Research and Analytical Reviews (IJRAR), E-ISSN 2348-1269, P- ISSN 2349-5138, Volume.12, Issue 2, Page No pp.713-721, June 2025, Available at : http://www.ijrar.org/IJRAR25B4663.pdf*
- *Sarvesh Kumar Gupta, 2025. "Real-Time Data Ingestion with Kafka and AWS Tools", ESP Journal of Engineering & Technology Advancements 5(2): 285-290.*
- *Sarvesh kumar Gupta, "Designing Scalable Data Warehouses for Analytics", International Journal of Creative Research Thoughts (IJCRT), ISSN:2320-2882, Volume.13, Issue 7, pp.h868-h876, July 2025, Available at :http://www.ijcrt.org/papers/IJCRT2507898.pdf*

- *Strategic Decision Intelligence Using Predictive Analytics in Modern Organizations. (2026). Global Journal of Innovative Research Perspectives (GJIRP), 2(2), May (1-8). https://doi.org/10.63345/gjirp.v2.i2.201*
- *Sarvesh kumar Gupta. Best practices for oracle to PostgreSQL migration. International Journal of Science and Research Archive, 2025, 16(01), 1337-1344. Article DOI: https://doi.org/10.30574/ijsra.2025.16.1.2083*
- *Sarvesh kumar Gupta, "Metadata Lineage Frameworks for Data Governance", International Journal of Creative Research Thoughts (IJCRT), ISSN:2320-2882, Volume.13, Issue 9, pp.c895-c903, September 2025, Available at :http://www.ijcrt.org/papers/IJCRT2509332.pdf*
- *Gupta, S. K. (2025). Machine Learning Integration in Spark-Based Pipelines. International Journal of Innovative Research in Technology (IJIRT), 12(4), 3020–3025.*
- *Sarvesh Kumar Gupta, 2025. "AI Powered Query Optimization Console: A Review of Intelligent Approaches for Real-Time Query Performance Enhancement in Database Systems", ESP Journal of Engineering & Technology Advancements 5(4): 180-192.*
- *Bharucha, S. (2026). Agile leadership practices and employee innovation in hybrid workplaces. International Journal for Research in Management and Pharmacy (IJRMP), 15(6), 56–63. https://doi.org/10.63345/ijrmp.v15.i6.1*
- *Sarvesh Kumar Gupta. Cloud ETL optimization with AWS glue and spark. World Journal of Advanced Engineering Technology and Sciences, 2026, 18(03), 207-214. Article DOI: https://doi.org/10.30574/wjaets.2026.18.3.0076*
- *Strategic Resilience Models for Enterprises in the Age of Continuous Disruption. (2026). E-Journal of Science and Emerging Technologies (EJSET), 2(2), May (26-33). https://doi.org/10.63345/ejset.v2.i2.201*
- *Bharucha, S. (2023). Digital legacy and innovation balance in family-owned enterprises. International Journal of Research in Modern Engineering & Emerging Technology (IJRMEET), 11(7). https://doi.org/10.63345/ijrmeet.org.v11.i7.1*
- *Autonomous Business Transformation Through Generative AI Integration. (2026). Global Journal of Innovative Research Perspectives (GJIRP), 2(2), Apr (83-91). https://doi.org/10.63345/gjirp.v2.i2.101*
- *Bharucha, S. (2023). Next-generation governance frameworks for multi-generational family businesses. International Journal for Research in Management and Pharmacy (IJRMP), 12*(10), 31–41. https://doi.org/10.63345/ijrmp.v12.i10.5*
- *Strategic Leadership for Hybrid Human–AI Workforce. (2025). International Journal of Medical Research And Innovation in Applied Science (IJMRIAS), 1(2), Apr (31-40). https://doi.org/10.63345/ijmrias.v1.i2.101*
- *Bharucha, S. (2022). Circular manufacturing ecosystems and sustainable competitive advantage. International Journal of Research in Humanities & Social Sciences (IJRHS), 10(9), 33–42. https://doi.org/10.63345/ijrhs.net.v10.i9.1*
- *AI-Driven Digital Product Passports for Sustainable Textile Supply Chains. (2025). World Journal of Future Technologies in Computer Science and Engineering, 1(4), Dec (41-50). https://doi.org/10.63345/wjftcse.v1.i4.301*
- *Bharucha, S. (2022). Predictive restructuring frameworks for organizational renewal. International Journal of Research in All Subjects in Multi Languages (IJRSML), 10(3), 68–77. https://doi.org/10.63345/ijrsml.v10.i3.1*
- *Bharucha, S. (2024). Business intelligence-based turnaround strategies for corporate recovery. International Journal for Research in Education (IJRE), 13 (8), 10–19. https://doi.org/10.63345/ijre.v13.i8.1*
- *Generative AI and the Reinvention of Management Education. (2026). Scientific Journal of Artificial Intelligence and Blockchain Technologies (SJAIBT), 1(2), Jun (1-9). https://doi.org/10.63345/sjaibt.v1.i2.301*