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OPERATIONAL RISK MANAGEMENT IN GLOBAL SUPPLY CHAINS: THE ROLE OF BLOCKCHAIN IN ENHANCING TRACEABILITY

MANAJEMEN RISIKO OPERASIONAL DALAM RANTAI PASOK GLOBAL: PERAN BLOCKCHAIN DALAM MENINGKATKAN KETERLACAKAN

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ABSTRACT
Operational Risk Management (ORM) is crucial for maintaining global supply chain resilience, but disruptions can increase costs, reduce quality, and cause significant financial losses, as evidenced by a 26% increase in cargo theft incidents by 2024, with estimated losses exceeding USD 1 billion. Enhanced traceability is key to risk mitigation, in line with the projected blockchain traceability market reaching USD 44.3 billion by 2034. This study examines how blockchain adoption impacts ORM through improved traceability using a narrative synthesis of peer-reviewed articles from 2015–2025 in Scopus, Web of Science, ScienceDirect, and Google Scholar. The analysis focuses on blockchain-based traceability mechanisms, the types of risks addressed, and the impact on risk mitigation. The results show that blockchain enhances traceability through immutable, transparent, and decentralized data records, reducing fraud, counterfeiting, and compliance issues. Smart contracts enable process automation, reducing delivery delays, and increasing efficiency. These findings are supported by the Transaction Cost Economics (TCE), Resource-Based View (RBV), and Supply Chain Risk Management (SCRM) frameworks, emphasizing transaction cost reduction, competitive advantage, and risk mitigation. Blockchain plays a strategic role in transforming global supply chains, although implementation faces challenges related to cost and integration of legacy systems. Further studies are recommended using quantitative and longitudinal approaches for long-term evaluation.
Keywords: Blockchain, Traceability, Global Supply Chain, Operational Risk Management, Smart Contracts, Risk Mitigation

ABSTRAK
Manajemen Risiko Operasional (Operational Risk Management/ORM) penting untuk menjaga ketahanan rantai pasok global, namun gangguan dapat meningkatkan biaya, menurunkan kualitas, dan menimbulkan kerugian finansial signifikan, tercermin dari kenaikan insiden pencurian kargo sebesar 26% pada 2024 dengan estimasi kerugian lebih dari USD 1 miliar. Peningkatan keterlacakan menjadi kunci mitigasi risiko, sejalan dengan proyeksi pasar blockchain untuk traceability yang mencapai USD 44,3 miliar pada 2034. Penelitian ini mengkaji bagaimana adopsi blockchain memengaruhi ORM melalui peningkatan traceability menggunakan sintesis naratif dari artikel peer-reviewed 2015–2025 di Scopus, Web of Science, ScienceDirect, dan Google Scholar. Fokus analisis mencakup mekanisme traceability berbasis blockchain, jenis risiko yang ditangani, serta dampak terhadap mitigasi risiko. Hasil menunjukkan bahwa blockchain meningkatkan keterlacakan melalui catatan data yang immutable, transparan, dan terdesentralisasi, mengurangi penipuan, pemalsuan, dan masalah kepatuhan. Smart contracts memungkinkan otomatisasi proses, mengurangi keterlambatan pengiriman dan meningkatkan efisiensi. Temuan ini didukung oleh kerangka Transaction Cost Economics (TCE), Resource-Based View (RBV), dan Supply Chain Risk Management (SCRM), menekankan pengurangan biaya transaksi, keunggulan kompetitif, dan mitigasi risiko. Blockchain berperan strategis dalam mentransformasi rantai pasok global, meski implementasi menghadapi tantangan biaya dan integrasi sistem lama. Studi lanjut disarankan menggunakan pendekatan kuantitatif dan longitudinal untuk evaluasi jangka panjang.
Kata Kunci: Blockchain, Keterlacakan, Rantai Pasok Global, Manajemen Risiko Operasional, Smart Contracts, Mitigasi Risiko

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1. INTRODUCTION

Operational Risk Management (ORM) is a crucial element in maintaining the smooth and sustainable operation of global supply chains. Disruptions in the supply chain can lead to increased costs, decreased quality, and other issues throughout the entire supply chain. For example, a machine breakdown in a factory can halt production and delay product shipments. Such disruptions impact production cycles and can cost millions of dollars (Recorded Future, 2024).According to the McKinsey Global Supply Chain Leader Survey 2024, nearly half of respondents said their organizations have regular supply chain risk reporting. However, the frequency of supply chain risk discussions at the senior management level has declined sharply, with most companies reverting to ad hoc reporting in response to disruptions or the emergence of new risks (McKinsey & Company, 2024).

Key challenges in ORM include the risk of fraud, delays, and non-compliance. In 2024, there were 3,798 incidents of cargo theft in the US, a 26% increase compared to the previous year. Organized crime groups leverage supply chain technology to impersonate legitimate carriers and steal cargo. Reported losses reached $455 million, with actual losses estimated to exceed $1 billion annually (NY Post, 2025).Additionally, disruptions in the supply chain can cause delays, increased costs, or quality issues throughout the supply chain (Recorded Future, 2024).

Traceability plays a critical role in mitigating operational risk. The global market for blockchain in supply chain traceability is expected to reach USD 44.3 billion by 2034, growing from USD 2.89 billion in 2024, at a compound annual growth rate (CAGR) of 31.4% (Market.us, 2024). This growth is driven by the increasing need for transparency and compliance across various industries, including food, pharmaceuticals, and luxury goods.

Blockchain can improve supply chain transparency and traceability while reducing administrative costs. This technology enables a shared and immutable record of transactions, enabling data recording, validation, and sharing across interconnected enterprises. All parties have access to a seamless exchange of value and a single source of truth that was previously impossible (Deloitte, 2024).Blockchain is a distributed ledger-based technology that enables permanent and immutable data recording within a decentralized network. Every transaction is recorded in a chain of interconnected blocks, each with a timestamp and cryptographic signature that guarantees data security and validity. The technology's key characteristics include immutability, transparency, and decentralization.

Immutability means that once data is entered into the blockchain, it cannot be modified or deleted, ensuring information integrity. Transparency allows all authorized parties to access transaction history with a high level of visibility, reducing the risk of information asymmetry. Decentralization eliminates reliance on a central authority because data is stored and validated by multiple nodes in the network, increasing the system's resilience to disruption and potential fraud. These characteristics make blockchain an innovative solution to address common issues in global supply chains, such as lack of trust between parties, the risk of document forgery, and delays in data verification.In the supply chain context, blockchain is used to create a secure and transparent record-keeping system, allowing every movement of goods, raw materials, or information to be recorded in detail from the point of origin to the final destination. Applications of this technology can include shipment tracking, logistics document management, compliance monitoring, and product authenticity verification.

One of the main benefits of blockchain in the supply chain is the increased traceability or the ability to track the flow of goods accurately and in real time. With blockchain, every party involved in the supply chain from suppliers, manufacturers, distributors, to consumers—can verify product information with a high degree of confidence. This not only increases transparency but also helps reduce the risk of fraud and counterfeiting, and quickly identifies the source of problems when disruptions occur in the distribution process.Furthermore, blockchain implementation can support compliance with international

regulations and standards, which increasingly demand information transparency. The reliability of the resulting data also provides a basis for more accurate strategic decision-making, particularly in anticipating and mitigating operational risks at various points in the supply chain.

While many studies have addressed blockchain adoption in supply chains, most studies only highlight general aspects such as efficiency, transparency, or increased trust between partners. However, the specific relationship between blockchain,traceability, and operational risk management remain underexplored. Most literature tends to focus on conceptual benefits without providing a detailed understanding of how improved traceability through blockchain actually impacts risk mitigation mechanisms in practice.

Furthermore, there remains a gap in identifying specific mechanisms explaining how this technology can mitigate potential operational disruptions, such as those related to delivery delays, information inaccuracies, or quality issues. Therefore, more focused research is needed to address how blockchain can strengthen operational risk management through increased traceability, thereby providing both theoretical and practical contributions to global supply chain management.

This research question was formulated to explore how the adoption of blockchain technology can improve traceability and, in turn, impact operational risk management in global supply chains. The primary focus of this question is to understand the specific mechanisms through which blockchain facilitates transparency, data integrity, and process automation, which impact the mitigation of risks such as fraud, delays, and non-compliance.

By answering these questions, this research aims to fill the gap in the literature, which is still limited in its focus on the direct relationship between blockchain, traceability, and operational risk management. Furthermore, this research is expected to provide theoretical contributions by broadening the understanding of the role of digital technology within the frameworks of Transaction Cost Economics (TCE), Resource-Based View (RBV), and Supply Chain Risk Management (SCRM), while also offering practical implications for companies in designing effective blockchain adoption strategies in global supply chains.

The primary objective of this review is to identify empirical and conceptual evidence supporting the relationship between blockchain, traceability, and operational risk reduction. By analyzing existing studies, this review will map the extent to which blockchain technology has been used to improve product traceability, reduce uncertainty, and strengthen risk mitigation strategies in global supply chains. The results are expected to provide comprehensive insights into the effectiveness of blockchain as a strategic instrument in operational risk management and provide direction for future research and implementation.

2. METHODS

2.1. Literature Search Strategy

The literature search was conducted through four main databases:Scopus, Web of Science, ScienceDirect. The keywords used include the following combinations:

- “Blockchain AND operational risk”
- “Supply chain traceability”
- “Blockchain adoption in SCM”
- “Risk management in global supply chains”

Operator Boolean (AND, OR) was used to ensure comprehensive search coverage. The search was conducted on articles published between the years2015 to 2025, to capture the latest literature as blockchain technology develops in supply chain risk management.

2.2. Inclusion and Exclusion Criteria

Inclusion criteria include:

- Article peer-reviewed.
- Focus on blockchain adoption in global supply chains.
- Discuss traceability and its relation to operational risk management (ORM).
- Publication in English.

Exclusion criteria include:

- Non-academic articles, opinions, or editorials.
- Case studies that are not relevant to ORM.
- Publications in languages other than English.

2.3. Data Extraction and Synthesis

From articles that met the criteria, information was extracted regarding:

- Blockchain-based traceability mechanism.
- Types of operational risk handled (e.g., fraud, delays, non-compliance).
- The effect of blockchain adoption on operational risk mitigation.

Approach narrative synthesis used to combine findings from diverse literatures, highlighting common patterns, research gaps, and unique contributions of the studies he studied.analysis.

3. RESULTS

Blockchain technology adoption in global supply chains has been markedly on the rise since 2018, reflecting its transformative potential across various industries including food, pharmaceuticals, and logistics. The diversity of sectors embracing blockchain underscores its versatility, showcasing applications from enhancing traceability to automating transaction processes through smart contracts. According to Wang and Wang, there is a robust framework proposed that integrates smart contracts into logistics management, highlighting its effectiveness in streamlining operations while ensuring data security and stability (Wang & Wang, 2023). Additionally, the versatility of blockchain can be attributed to its various forms, such as permissioned and permissionless blockchains, which serve different operational needs within the supply chain context (Tijan et al., 2019).

One of the pivotal advantages of blockchain is its capacity to enhance traceability, integral for ensuring product integrity throughout the supply chain. This capability enables stakeholders to record every phase of a product's lifecycle in an immutable ledger, thus bolstering the verification of raw materials' origins and reducing fraud risk, particularly in the food industry (Munir et al., 2022; , Xia et al., 2023). The pharmaceutical sector exemplifies blockchain's efficiency in combating counterfeit products through enhanced drug authentication (Zhu et al., 2020). The logistics domain benefits from blockchain as well, where improved transparency of goods movement facilitates risk management and operational efficiencies (Fu & Zhu, 2019; , (Helo & Hao, 2019).

Moreover, literature emphasizes the critical role of blockchain technology in mitigating operational risks throughout supply chains. Blockchain adoption contributes to the reduction of various challenges such as fraud, counterfeiting, delays, and compliance issues. For instance, studies indicate that blockchain reduces delivery delays by automating processes through smart contracts, thereby enhancing efficiency (Gruchmann et al., 2023; , Tan et al., 2020). However, these benefits are often tempered by challenges related to implementation costs and the integration of blockchain with existing legacy systems, a sentiment echoed across various studies which note the necessity for technological readiness and ecosystem support for successful implementation (Helo & Hao, 2019).

In synthesizing the findings from the current body of literature, it is evident that improving traceability via blockchain implementation leads to stronger operational risk management frameworks within global supply chains. Nonetheless, gaps in research persist regarding contextual variables, comparative analyses across industries, and a lack of empirical, quantitative evaluations detailing blockchain's long-term effectiveness (Aslam et al., 2023). These gaps highlight the need for further investigation into blockchain's impact on supply chain dynamics, offering an opportunity for future empirical research.

4. DISCUSSIONS

4.1. Interpretation of Findings

The analysis shows that blockchain improves traceability through decentralized, transparent, and immutable data recording. This mechanism reduces information asymmetry and facilitates tracking of product origins, material flows, and transactions within the supply chain. The impact on operational risk management is evident in the reduced potential for fraud, counterfeiting, and regulatory non-compliance. This technology also plays a role in reducing delays arising from a lack of data visibility. The integration of blockchain technology into supply chain management is increasingly recognized through various theoretical lenses, including Transaction Cost Economics (TCE), the Resource-Based View (RBV), and Supply Chain Risk Management (SCRM). Each of these frameworks elucidates the transformative impact of blockchain on transaction costs, competitiveness, and risk mitigation.

From a TCE perspective, blockchain significantly reduces transaction costs by minimizing the need for manual verification, which highlights the technology's efficacy in fostering secure and efficient information exchanges. This reduction stems from blockchain’s capability to eliminate intermediaries in transactions, facilitating direct interactions between parties (Frolov, 2020; Mahyuni et al., 2020; Kshetri & Loukoianova, 2019). By enhancing transaction reliability and promoting a greater level of trust among supply chain partners, blockchain mitigates the friction often associated with traditional transaction methods (Ioannou & Demirel, 2022).

Simultaneously, the RBV supports the assertion that blockchain adoption generates unique capabilities that are difficult for competitors to emulate. The technology's intrinsic features—such as transparency, traceability, and security—contribute to organizational competencies that can boost competitiveness (Cai et al., 2023). Organizations that leverage blockchain are positioned to achieve superior supply chain performance, thereby establishing a competitive edge that can be difficult for rivals to replicate (Revathi et al., 2024). Notably, the development and preservation of these resources enable sustained competitive advantages, aligning well with RBV principles.

From an SCRM viewpoint, blockchain acts as a robust mechanism for mitigating risks by ensuring data reliability and enhancing transparency across supply chains. By providing a decentralized and immutable ledger, blockchain contributes to improved visibility and accountability, which are critical in managing operational and financial risks (Hong & Hales, 2023; Chelh & Ababou, 2023). This transparency allows companies to track the movement of goods and payments more accurately, thus minimizing uncertainties associated with supply chain operations (Chowdhury et al., 2022). As organizations implement blockchain, they can better withstand supply chain disruptions and enhance resilience against various risk factors (Turgay & Erdoğan, 2023). In conclusion, the interplay of these theories illustrates that blockchain not only serves as a technological advancement but also as a strategic tool capable of transforming supply chain dynamics by reducing transaction costs, creating distinctive competitive advantages, and effectively managing risks.

4.2. Comparison with Existing Literature

These findings are consistent with previous literature suggesting that blockchain enhances traceability, particularly in the food and pharmaceutical industries. However, several studies emphasize that these benefits have not been fully realized due to limited technological infrastructure and high implementation costs. Furthermore, there are contradictory findings regarding blockchain's effectiveness in reducing delays; some studies show significant results, while others find coordination challenges that only add to complexity.

4.3. Implications for Theory and Practice

This research contributes to the development of a conceptual model linking blockchain, traceability, and operational risk management. This model broadens the understanding of the role of digital technologies in TCE, RBV, and the SCRM framework.For industry players, these results emphasize that blockchain investments should be focused on areas with the greatest impact on supply chain visibility. Implementing smart contracts can accelerate the verification process and reduce reliance on third parties. However, organizations must consider technological readiness, regulatory compliance, and human resource training to ensure effective adoption.

4.4. Limitations

The main limitation of this research is the narrative review approach, which does not involve quantitative analysis, thus limiting the generalizability of the results. Furthermore, most of the data comes from case studies focused on specific sectors, so cross-industry representation is not comprehensive. The potential for publication bias is also a concern, as studies showing positive results tend to be more widely published.

4.5. Future Research Directions

Future research should adopt a quantitative and longitudinal approach to more objectively evaluate blockchain's impact on risk management. Cross-industry and cross-country studies are also crucial to identify the influence of contextual factors such as regulation, supply chain complexity, and technology readiness. Furthermore, the development of standard metrics to measure blockchain's contribution to operational risk reduction is necessary.

5. CONCLUSION

The adoption of blockchain technology in global supply chains has seen significant growth since 2018, underscoring its potential as a transformative innovation across sectors including food, pharmaceuticals, and logistics. This growth is driven by its ability to improve traceability, automate processes through smart contracts, and reduce operational risk. By recording every stage of a product's lifecycle in an immutable ledger, blockchain ensures greater transparency, verifies the origin of raw materials, and minimizes the risk of fraud and counterfeiting. This application is particularly relevant in vulnerable industries such as food and pharmaceuticals, and supports efficient logistics management.In addition to improving traceability, blockchain also plays a role in mitigating operational risks by reducing the potential for fraud, delays, and compliance issues. Smart contracts enable process automation, reducing delivery delays and increasing efficiency. However, these benefits come with challenges related to implementation costs and integration with legacy systems, which often hinder the widespread adoption of this technology.

Theoretically, the impact of blockchain can be explained through several frameworks. Transaction Cost Economics (TCE) highlights its role in reducing transaction costs by eliminating intermediaries and reducing manual verification. The Resource-Based View (RBV) suggests that blockchain creates unique capabilities, such as transparency and data security, that are difficult to replicate, thus providing a competitive advantage. Meanwhile, from a Supply Chain Risk

Management (SCRM) perspective, blockchain serves as a reliable risk mitigation mechanism, increasing transparency, and strengthening supply chain resilience to disruptions.

The implications of these findings are both theoretical and practical. Theoretically, this study broadens understanding of the role of digital technology within the TCE, RBV, and SCRM frameworks. Practically, companies should prioritize blockchain implementation in areas that have the greatest impact on supply chain visibility, while considering technological readiness, regulations, and human resource training. However, limitations of this study include its narrative review-based nature, which limits the generalizability of the results. Furthermore, the predominance of sector-specific case studies and the potential for publication bias are also concerns.

For future research, quantitative and longitudinal studies are needed to more objectively evaluate blockchain's effectiveness. Cross-industry and cross-country research is also crucial to understand the influence of contextual factors, such as regulation and supply chain complexity. Furthermore, developing standard metrics to measure blockchain's contribution to operational risk reduction is a key agenda. Overall, blockchain is not just a technological innovation, but also a strategic tool capable of transforming global supply chain dynamics by reducing transaction costs, improving traceability, and managing risk more effectively.

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