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Integrating Blockchain and Artificial Intelligence to Enhance Supply Chain Resilience: Evidence from Algerian Organizations

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Abstract :
This study investigates the impact of integrating blockchain and Artificial Intelligence (AI) on supply chain resilience in Algerian organizations. Data were collected through a questionnaire (140 valid responses) and analyzed using SPSS and Chi-square tests. The results indicate that both technologies significantly improve efficiency, transparency, and risk management, while their integration further enhances real-time visibility and responsiveness to disruptions. The study confirms the importance of adopting integrated digital technologies to strengthen supply chain resilience.
Keywords: Blockchain, Artificial Intelligence, Supply Chain, Resilience
Jel Classification Codes: L14, M15, O33

Introduction :

In today's fast-paced world, organizations face unprecedented challenges due to technological advancement, market fluctuations, environmental concerns, and the continuous evolution of customer needs and competitive requirements. These challenges have driven organizations to seek greater integration with suppliers and customers within their supply chains.

Supply chains play a critical role in organizations, as they contribute to creating customer value and ensuring satisfaction. A supply chain encompasses a network of relationships connecting suppliers, producers, service providers, distributors, and customers. It covers all activities and stages related to production and sales, from sourcing raw materials, transforming them into products, to delivering them to the final customer. However, the complexity resulting from multiple actors and processes has increased the vulnerability of supply chains to disruptions and risks. Furthermore, the lack of transparency in some stages has made process tracking difficult and has led to challenges related to manipulation or operational errors. In this context, there is a growing need to build more resilient supply chains capable

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of anticipating disruptions, responding to them, and recovering quickly and effectively.

In the era of digital transformation, there is an increasing shift towards leveraging technological solutions to enhance supply chain efficiency and resilience. Among these technologies, blockchain has emerged as a promising solution due to its ability to enhance transparency, security, traceability, and integration across supply chain stages. Similarly, artificial intelligence (AI) enables smarter data analysis, precise decision-making, and prediction of future events. Overall, the integration of blockchain and AI is driving a fundamental transformation in supply chain management practices, reshaping how organizations manage logistics and supply chain operations.

1. Research Problem

Based on the above, the following central question arises:

What is the impact of integrating blockchain and artificial intelligence on supply chain resilience?

To explore key aspects of the study, the following sub-questions can be formulated:

- What is the impact of blockchain technology on enhancing supply chain resilience?
- What is the impact of artificial intelligence on enhancing supply chain resilience?
- What is the impact of integrating blockchain and artificial intelligence on enhancing supply chain resilience?

2. Research Hypotheses

To address the research problem, the following hypotheses are proposed:

1. Blockchain technology has a statistically significant effect on enhancing supply chain resilience.
2. Artificial intelligence has a statistically significant effect on enhancing supply chain resilience.
3. The integration of blockchain and artificial intelligence has a statistically significant effect on enhancing supply chain resilience.

3. Significance of the Study

The significance of this study stems from the importance of understanding how to enhance supply chain resilience using advanced and intelligent technologies. Specifically, it focuses on the integration of blockchain and artificial intelligence within supply chains and examines the impact of their combined application on improving resilience.

1- Theoretical Framework of Blockchain Technology :

Blockchain technology offers advanced potentials in multiple fields, which has led to increasing interest in academic, industrial, and service sectors. The first emergence of this technology dates back to late 2008, associated with the launch of digital currencies—Bitcoin—when an anonymous person using the pseudonym Satoshi Nakamoto published a research paper presenting a decentralized peer-to-peer electronic cash system called Bitcoin. At that time, few participants realized that blockchain technology could have a significant impact in various fields, including business practices (Marzouq, 2021).

1-1- Definition of Blockchain Technology

Blockchain is among the recent terms in the field of digital technology. Several definitions have been proposed:

Blockchain technology is defined as multiple blocks linked together to form a blockchain network, where each block contains numerous transactions aggregated using cryptographic techniques to ensure their integrity (Guo & Liang, 2016).

It is also defined as a database that includes all exchanges occurring among clients since its creation, with all blocks encrypted. It is possible to add information, but deletion or alteration of content is impossible, imparting a property of transparency to this technology (Seabacher & Schurit, 2017).

Moreover, blockchain technology is described as a technology that integrates several computer technologies, including distributed data storage, peer-to-peer transmission, consensus mechanisms, and cryptographic algorithms (Laforet, 2022).

Based on the above, blockchain can be defined as a collection of transaction records linked sequentially and encrypted, distributed across the network's nodes. It relies on a set of computer technologies such as distributed ledger technology, peer-to-peer networking, and cryptographic algorithms. Transactions are stored in a permanent ledger without the need for intermediaries, in a decentralized manner characterized by high transparency and security.

1-2- Characteristics of Blockchain Technology

Blockchain technology possesses several unique characteristics, summarized as follows:

- **Decentralization:** Blockchain is based on decentralization, eliminating intermediaries by using consensus algorithms, which maintain data consistency, reduce hacking risks, and prevent data loss (Hewa, Ylianttila, & Liyanage, 2021).
- **Transparency:** This property is achieved through the visibility of every transaction and its associated values to every authorized user while maintaining the confidentiality of actual identities. Any verification or modification of information requires approval from other members (Habib et al., 2022).
- **Immutability:** Transactions are permanently recorded in a distributed ledger among participating nodes, making it impossible to modify or delete records after registration, thereby enhancing data integrity and distinguishing blockchain from centralized databases (Bajolle & Godé, 2021).
- **Security:** All linked blocks and their variables can be read and historically traced, facilitating auditing and tracking transaction details, which reduces the likelihood of tampering or fraud in the public ledger stored across all network devices (Nouri & Shtouh, 2022).
- **Traceability:** Distributed ledgers are automatically updated, recording transaction times and related events (Rennock & Alan, 2022).
- **Cost Reduction and Transaction Speed:** The absence of third-party intermediaries reduces costs, as the public ledger is distributed across all network devices. Any participant can access, settle, and audit transactions directly and instantly, increasing transaction speed.

1-3- Components and Types of Blockchain Technology

Since its inception, blockchain technology has evolved into four generations. The first generation is the most famous, focused on cryptocurrencies. The second generation includes distributed ledger agreements and some technological components such as smart contracts and protocols. The third generation extends beyond organizational and sectoral frameworks, introducing the concept of decentralized autonomous organizations, while the fourth generation integrates blockchain with artificial intelligence technologies (Hamada, 2022).

Blockchain technology enables a range of important functions through interconnected components, including (Safar & Shershem, 2022):

- **Block:** The fundamental building unit of the chain, encompassing operations such as data recording, processing, fund transfer, and transaction monitoring. Transactions are aggregated into blocks of limited capacity and linked via hash codes, forming a blockchain.
- **Hash:** A function that encrypts inputs of varying sizes and converts them into fixed-size outputs expressed through unique codes. Any modification in a block results in changes to all hashes in the chain.
- **Transaction (Information):** Refers to an individual operation within a block that collectively represents the block.
- **Node:** Represents all users of devices within the blockchain network who primarily hold identical copies of executed transactions.

Due to varying purposes of blockchain usage among participants, there are different types to meet diverse objectives. Public blockchains are decentralized systems allowing all participants to access data, verify, exchange, and add blocks. Private blockchains operate with clearly identified, pre-approved users responsible for authentication and validation. Hybrid blockchains combine public and private features (Lesueur-Caze, Bironneau, Lux, & Thierry, 2022).

Based on access restriction, blockchains are categorized into permissionless and permissioned: Permissionless blockchains are open-source ledgers accessible to anyone with an internet-connected computer, while permissioned blockchains impose restrictions at various levels depending on platform characteristics, whether private or public, and regarding proposing new transactions, transaction validation, or data reading (Zheng, Dai, Xie, Xiangping, & Wang, 2018).

2-Theoretical Framework of Artificial Intelligence

Artificial Intelligence (AI) is considered one of the most significant terms in the modern technological world. Its importance lies in its ability to simulate human thinking, interact with complex environments, solve problems autonomously, and learn from past experiences.

2-1- Definition of Artificial Intelligence

During the Dartmouth Conference, John McCarthy first defined AI in 1956 as "the science and engineering of making intelligent machines." Subsequently, the concept evolved to include multiple definitions:

AI has been described as a new science aimed at enabling machines and computers to possess fully functional minds, automating activities associated with human intelligence such as decision-making, problem-solving, and learning. It is also defined as the science of creating machines and computers that perform functions requiring intelligence when executed by humans, studying how to make machines

and computers perform tasks that humans can accomplish more efficiently (Mujahid, 2020). Furthermore, AI is recognized as an intelligent system inspired by human intelligence, capable of developing logical rules, adapting to changing environments, learning from data, and performing complex tasks efficiently (Sarhan & Bouhlel, 2024).

Therefore, AI emulates human intelligence to accomplish human activities more intelligently and efficiently.

2-2- Types of Artificial Intelligence

AI can be classified based on performance levels and capabilities into three types (Boubidi & Letim, 2023):

- **Narrow AI:** Refers to computers performing a single task with high efficiency and repeatability, surpassing human capabilities in specific areas but not yet achieving human-level intelligence. Most current applications and devices fall under this category.
- **General AI:** Encompasses tasks at the human level, functioning autonomously without human intervention, e.g., self-driving cars.
- **Super AI:** Refers to AI systems that surpass human intelligence.

AI can also be classified according to its interaction with the environment, focusing on how intelligent systems operate and interact with data:

- **Reactive AI:** Relies on immediate responses to situations without storing previous data.
- **Predictive AI:** Analyzes data to detect patterns and predict future behavior.

2-3- AI Technologies

AI technologies include a wide range of tools and algorithms that help intelligent systems perform various functions:

- **Machine Learning:** Involves developing systems capable of learning from data and improving performance over time without direct human intervention, relying on algorithms to analyze large datasets and teach models how to make decisions or classify information (Dash et al., 2019).
- **Robotics:** Physical structures programmed or connected to computers to perform specific tasks with precision and efficiency.
- **Computer Vision:** Enables computer systems to understand images and videos as humans do, interpreting content to make informed decisions.
- **Natural Language Processing (NLP):** Allows computer systems to understand and analyze written and spoken human language, improving human-machine interaction (Belkhir, 2024).

3- Integrating Blockchain and AI in Supply Chains

3-1- Supply Chain in the Digital Age

Supply chains are no longer linear sequences of processes but complex, dynamic networks of organizations working together to meet customer needs. These networks span globally, integrating various entities, including suppliers, manufacturers, distributors, retailers, and service providers.

Supply chains encompass all activities related to the flow of products and information from sources to the end customer. Supply Chain Management (SCM) aims to achieve internal integration among internal supply systems, external

integration across different organizations, and coordination between both internal and external systems within the supply chain.

Traditional technologies such as Electronic Data Interchange (EDI), barcodes, and Enterprise Resource Planning (ERP) systems are no longer sufficient for achieving competitive advantage. To remain competitive, organizations must adopt modern digital technologies emerging from the second half of the Fourth Industrial Revolution 4.0, including cloud computing, big data analytics, the Internet of Things (IoT), blockchain, and AI, and integrate them into supply chain functions to enhance information collection, connectivity, and intelligent application (Abu Ward et al., 2022).

Thus, a smart supply chain can be defined as one supported by the internet and modern technologies, transforming it into a dynamic system capable of rapid restructuring and adaptation to external environments. Smart supply chains rely on digitalized core processes and are characterized by using digital and technological applications at all stages (Büyüközkan & Göçer, 2018).

Key benefits of smart supply chains include (Haydar & Kazem, 2025):

- Increased transparency and coordination among stakeholders.
- Enhanced collaborative and integrative relationships and partnerships.
- Improved operational efficiency.
- Data-driven decision-making.
- Greater resilience and adaptability to changes.

3-2- Blockchain and Supply Chain

Many organizations have transitioned from traditional to smart supply chains, relying on modern technologies to build flexible, interconnected business models, with blockchain being a key technology (Liu, 2021). Its use in supply chains is reliable and tamper-resistant because the distributed ledger consists of multiple copies, making manipulation extremely difficult since all copies must be altered simultaneously. Consequently, blockchain ensures high transparency and reduces risks of fraud and unethical practices.

The technology also provides full visibility of product origins, movement, and status across all supply chain stages, aiding product traceability. Smart contracts automatically update procedures upon meeting specific conditions, replacing slow manual processes with fast, flexible digital operations. Their use also automates tasks such as payments and inventory management, reducing costs, simplifying transactions, and eliminating intermediaries. Real-time verification shortens settlement times, while real-time data availability allows efficient inventory management and reduces waste (Kamble, Gunasekaran, & Sharma, 2020).

3-3- AI and Supply Chain

AI usage in supply chains has led to a fundamental transformation in planning, production, management, and process optimization. By processing vast amounts of data, predicting trends, and performing complex tasks in real time, AI enhances decision-making and operational efficiency (Haefner, Wincent, Parida, & Gassmann, 2021).

Machine learning surpasses traditional software capabilities, predicting customer demand, planning inventory, detecting patterns, forecasting markets, interpreting text and speech, and analyzing multiple factors to improve supply chain workflow and resilience. This includes optimizing product distribution, improving customer communication, reducing costs, enhancing operational efficiency, increasing

transparency, providing real-time monitoring tools, tracking, and managing manufacturing processes (Belhadi, Mni, Kamble, Khan, & Verma, 2021).

4- Field Study and Hypotheses Testing

This section addresses the field study, focusing on examining the impact of integrating Blockchain and Artificial Intelligence (AI) technologies on enhancing supply chain resilience in Algerian organizations. The field analysis aims to measure the effect of these technologies on improving both the resilience and operational efficiency of the supply chain.

4-1- Methodological Framework of the Study

4-1-1- Study Instrument Design

To address the research problem and test the hypotheses, a questionnaire was designed to collect the necessary data from the study sample. The questionnaire design considered theoretical insights and previous research findings. It also gathered information on respondents' demographics, including job position, educational qualification, and years of experience. A five-point Likert scale was used, where each statement has corresponding response options as shown in Table 1:

Table 1. Five-Point Likert Scale

Rating	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
Score	5	4	3	2	1

4-1-2- Population and Sample

The study population consisted of Algerian organizations. A random sample of 150 organizations was selected, targeting managers, department heads, and individuals responsible for purchasing and supply chain operations, as they possess the greatest understanding of the study context and organizational policies related to AI and Blockchain.

Ten questionnaires were excluded due to invalid responses, resulting in a final sample of 140 valid questionnaires that were analyzed statistically.

Table 2. Characteristics of the Study Sample

Variable	Category	Frequency	Percentage
Educational Qualification	Professional Certificate	70	50%
	University Degree	55	39.28%
	Postgraduate Degree	15	10.72%
Total		140	100%
Job Position	Manager	12	8.57%
	Department Head	38	27.10%
	Purchasing & Supply Officer	80	57.13%
Total		140	100%
Years of Experience	Less than 10 years	58	41.50%
	10–<20 years	45	32.10%
	More than 20 years	37	26.42%

Total		140	100%

Source: SPSS Statistical Analysis Results

Observations from Table 2:

- The highest educational qualification among respondents is the professional certificate (50%), followed by university degrees (39.28%), and postgraduate degrees (10.72%).
- The majority of respondents are purchasing and supply officers (57.13%), followed by department heads (27.10%), and managers (8.57%).
- The largest group based on years of experience has less than 10 years (41.50%), followed by 10–<20 years (32.10%) and more than 20 years (26.42%).

4-1-3- Validity and Reliability Testing of the Questionnaire

Ensuring the questionnaire's validity and reliability is critical. Validity refers to the instrument's ability to measure what it is intended to, while reliability ensures consistent results when administered under similar conditions. Table 3 presents the reliability (Cronbach's alpha) and validity of the questionnaire items

Table 3. Reliability and Correlation Coefficients for Questionnaire Items

Hypothesis	Statement	Item-Total Correlation	Cronbach's Alpha	Self-Validity
H1	Blockchain enhances data reliability in supply chain operations	0.858	0.946	0.973
	Blockchain enables visibility of changes in supply chain operations	0.839		
	Blockchain improves access to supply chain information	0.857		
	Blockchain contributes to rapid execution of supply chain processes	0.715		
	Blockchain reduces fraud and ensures operational safety	0.823		
	Blockchain lowers supply chain operational costs	0.817		
	Smart contracts enhance supply chain processes	0.833		
H2	AI organizes and improves supply chain methods	0.407	0.816	0.903
	AI aids in faster decision-making	0.546		
	AI reduces supply chain costs	0.671		
	AI reduces effort of supply chain members	0.671		
	AI analyzes customer data and predicts behavior	0.533		
	AI enables rapid knowledge storage regarding supply chain	0.473		
	AI effectively analyzes data to improve supply chain operations	0.626		
H3	Blockchain-AI integration promotes transparency, enhancing resilience	0.426	0.827	0.909

	Integration improves operational efficiency and resilience	0.493		
	Integration provides real-time insights	0.613		
	Integration reduces errors and enhances overall efficiency	0.477		
	Integration accelerates detection of anomalies	0.598		
	Integration ensures accurate and updated information	0.663		
	Integration enables networked information sharing	0.477		
Over all		0.948	0.974	

Source: SPSS Statistical Analysis Results

The Cronbach's alpha values exceed 0.60 and all item-total correlations exceed 0.30, indicating high reliability and no items were excluded. Self-validity scores are also high.

4-2- Statistical Analysis and Hypotheses Testing

Data collected from the questionnaire were analyzed using SPSS Version 26. Hypotheses were tested using descriptive statistics and the Chi-square (χ^2) test, a non-parametric test used to examine relationships between categorical variables.

4-2-1- Hypothesis 1 Testing

Table 4. Descriptive Statistics for Hypothesis 1

Statement	Mean	SD	Rank	Agreement Level
Blockchain enhances supply chain data reliability	3.67	1.05	6	High
Blockchain enables visibility of supply chain changes	3.72	0.81	5	High
Blockchain improves access to supply chain information	3.87	0.91	1	High
Blockchain contributes to rapid execution of processes	3.61	1.01	7	High
Blockchain reduces fraud and ensures operational safety	3.76	0.65	4	High
Blockchain lowers operational costs	3.78	0.82	3	High
Smart contracts enhance supply chain processes	2.81	0.89	2	Moderate

Source: SPSS Analysis Results

Table 5. Chi-Square Test for Hypothesis 1

Statement	χ^2 Calculated	Sig.
Blockchain enhances data reliability	112.33	0.000
Blockchain enables visibility of changes	124.74	0.000
Blockchain improves access to information	123.65	0.000
Blockchain contributes to rapid execution	95.53	0.000
Blockchain reduces fraud	94.66	0.000

Blockchain lowers costs	115.93	0.000
Smart contracts enhance processes	163.51	0.000

Source: SPSS Analysis Results

All χ^2 values exceed critical values and significance levels (Sig.) are <0.05, confirming acceptance of Hypothesis 1 (H1) and rejection of the null hypothesis (H0). Blockchain significantly impacts supply chain resilience at the 0.05 level.

4-2-2 Hypothesis 2 Testing

Table 6. Descriptive Statistics for Hypothesis 2

Statement	Mean	SD	Rank	Agreement Level
AI organizes and develops supply chain methods	3.86	1.06	6	High
AI aids in faster decision-making	3.74	0.97	7	High
AI reduces supply chain costs	4.05	0.61	4	High
AI reduces effort of supply chain members	4.10	0.85	3	High
AI analyzes customer data and predicts behavior	4.13	0.82	1	High
AI enables rapid knowledge storage	3.92	1.09	5	High
AI effectively analyzes data	4.12	0.78	2	High

Source: SPSS Analysis Results

Table 7. Chi-Square Test for Hypothesis 2

Statement	χ^2 Calculated	Sig.
AI organizes supply chain methods	90.60	0.000
AI aids in faster decision-making	142.07	0.000
AI reduces costs	138.96	0.000
AI reduces effort	164.13	0.000
AI predicts customer behavior	147.13	0.000
AI enables knowledge storage	113.13	0.000
AI analyzes data effectively	125.93	0.000

Source: SPSS Analysis Results

All χ^2 values exceed critical values and Sig. <0.05, confirming acceptance of Hypothesis 2 (H2). AI has a statistically significant effect on enhancing supply chain resilience at the 0.05 level.

4-2-3 Hypothesis 3 Testing

Table 8. Descriptive Statistics for Hypothesis 3

Statement	Mean	SD	Rank	Agreement Level
Blockchain-AI integration promotes transparency	4.37	0.81	3	Very High
Integration improves operational efficiency	4.49	0.72	5	Very High
Integration provides real-time insights	4.51	0.95	2	Very High
Integration reduces errors and enhances efficiency	4.42	0.92	4	Very High
Integration accelerates anomaly detection	4.36	0.76	7	Very High
Integration ensures accurate, updated information	4.39	0.86	6	Very High

Integration enables networked information sharing	4.65	0.74	1	Very High

Source: SPSS Analysis Results

Table 9. Chi-Square Test for Hypothesis 3

Statement	χ^2 Calculated	Sig.
Integration promotes transparency	172.73	0.000
Integration improves efficiency	185.60	0.000
Integration provides insights	136.46	0.000
Integration reduces errors	120.73	0.000
Integration accelerates anomaly detection	172.86	0.000
Integration ensures accurate information	140.53	0.000
Integration enables networked sharing	106.05	0.000

Source: SPSS Analysis Results

All χ^2 values exceed critical values and Sig. <0.05, confirming acceptance of Hypothesis 3 (H3). The integration of Blockchain and AI has a statistically significant impact on enhancing supply chain resilience at the 0.05 level.

Conclusion:

This study aimed to examine the impact of integrating Blockchain and Artificial Intelligence (AI) technologies on enhancing supply chain resilience in Algerian organizations. The empirical results demonstrated that both technologies individually contribute significantly to improving operational efficiency, transparency, and risk management within supply chains. More importantly, the findings revealed that their integration generates a complementary and synergistic effect, leading to greater real-time visibility, improved data accuracy, faster decision-making, and enhanced responsiveness to disruptions.

These results confirm that the adoption of advanced digital technologies is no longer optional but has become a strategic necessity for organizations seeking to build resilient and adaptive supply chains in an increasingly uncertain and dynamic environment. The study also provides practical implications for managers and decision-makers, encouraging them to invest in integrated technological solutions to improve coordination, reduce operational risks, and strengthen overall performance.

Future research is recommended to expand the scope by including larger and more diverse samples, as well as examining additional factors such as organizational readiness, technological infrastructure, and regulatory frameworks.

In conclusion, the integration of blockchain and AI represents a promising pathway toward achieving sustainable, efficient, and resilient supply chains in the era of digital transformation.

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