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Return of Investment for Food Blockchain Traceability Systems

Dimitris Papakyriakopoulos,
Department of Business Administration
University of West Attica, 250 Thivon Ave, Egaleo, 122 41, Greece.

Faidon Komisopoulos,
Department of Business Administration
University of West Attica, 250 Thivon Ave, Egaleo, 122 41, Greece.

Theodoros Xanthopoulos
Department of Business Administration
University of West Attica, 250 Thivon Ave, Egaleo, 122 41, Greece.

***Abstract*—The issue of Return on Investment (ROI) for blockchain traceability systems in Food sector is found to be quite untapped by the researchers. The importance of the subject is obvious, concerning the big amount of effort and investments that have to be made in order to establish trust and transparency across the food supply chain. Return on Investment (ROI) is a financial metric used to evaluate the profitability or efficiency of an investment. Blockchain in traceability systems enhances transparency, security, and efficiency in tracking and verifying the journey of products, services, or data across a supply chain. From the literature review and the studied bibliography, it was found that Return on Investment is not widely used blockchain-based traceability services (BBTS) especially in the agri-food supply chain and in general. In the few cases that Return on Investment is used, it was found that even though the revenue increase from the adaptation of such a system is taken into account, the cost savings from the adaptation is neglected during calculations of the gain from the investment.**

Keywords: Return on Investment, Blockchain, Traceability Systems Introduction (Heading 1)

I. INTRODUCTION

Gaining a comprehensive understanding of the potential return on investment (ROI) associated with adopting innovative technologies is crucial for stakeholders in the food industry. By meticulously analyzing the financial benefits and efficiencies that these advancements can bring, stakeholders can take the best possible decisions that align with their goals (Bombaywala & Riandita, 2015). This informed decision-making process can significantly contribute to enhanced food safety measures, as advanced technologies often implement rigorous monitoring systems and data analytics that can detect potential hazards more effectively than traditional methods. (Vangay, 2014) (Soby et al., 1994) Furthermore, the adoption of these technologies can lead to a marked reduction in food waste, as improved tracking and management systems allow for better inventory control and spoilage prevention (Dong et al., 2022).

Ultimately, these improvements not only bolster operational efficiency but also play a big role in enhancing consumer confidence in food products. When consumers are assured of the safety y of what they purchase, it fosters a stronger trust in brands and encourages loyalty. Thus, understanding the potential ROI is not just about financial gains; it encompasses broader implications for public health, sustainability, and consumer relationships in the ever-evolving food landscape (Choe et al., 2009). The objective of this paper is to highlight the adoption of blockchain food traceability platforms from information technology investment perspective.

The large number of factors need to be considered is an important challenge both for decision makers and for academics. Food is an important commodity for social life and attracts the interest from social scientists to policy makers. It is possible to recognize three levels of interaction namely technological, organizational, and environmental factors. From an IT investment perspective, organizations must carefully consider these factors for successful implementation of blockchain platforms. By addressing these factors, organizations can harness the potential of blockchain technology to enhance transparency, traceability, and efficiency in the food supply chain.

Technological factors are the most profound when dealing with the adoption of blockchain technology. Blockchain technology must be compatible with existing IT infrastructure and systems used by organizations in the food supply chain, making compatibility and interoperability an significant adoption factor. In the same manner, the high realization and maintenance costs of blockchain technology platforms could be significant barriers to

adoption. Supply chain trading partners consider the cost of developing and maintaining collaboration platforms, as well as the training cost employees to use the technology effectively (Mbadlisa and Jokonya, 2024). Other technological issues are related to Data Security and Privacy (Thoukidides et al., 2025), ease of use (Maniam et al., 2023). On top of that, recent academic studies explored the organization setting and found that firm size and tangible and intangible resources (e.g. knowledge and skills) are important factors concerning the adoption of blockchain (Mbadlisa & Jokonya, 2024), the top management support and the leadership culture determines the utilization of blockchain (Nandhini et al., 2024). Finally the context has a significant role because companies must comply with relevant regulations and standards when implementing blockchain platforms (Mbadlisa & Jokonya, 2024), the consumer demand for transparency in the food supply chain is another important contextual factor (Vignesh et al., 2024) etc.

II. Literature Review

A. Return on Investment

Return on Investment (ROI) is a financial metric used to evaluate the profitability or efficiency of an investment. It measures the return or gain from an investment relative to its cost. ROI is commonly used to compare the profitability of different investments or to determine whether a specific investment is worth pursuing.

The formula for ROI is as follows:

$$\boldsymbol{ROI} = \frac{\text{Net Profit (Gain from Investment)}}{\text{Cost of Investment}} \times 100$$

Where: Net Profit = Total Revenue or Benefits - Total Costs and Cost of Investment = Initial amount spent on the investment (Rohs, F. 2004).

The result is a percentage. The higher, the more profitable the investment is. ROI provides a simple way to measure whether an investment is worthwhile. For example:

- If ROI = **50%**, it means that 50% of the initial investment is gained as profit.
- If ROI = **-10%**, it means that a 10% of the investment is lost.

An example of ROI Calculation in Stock Investment is presented: Suppose shares of a stock are bought for $1,000. After one year, the shares are sold for $1,200. So the ROI is (1,200−1,000)/1,000×100=20%. This means that the return on investment is 20%.

ROI is useful because it is a Simple metric to Understand, Easy to calculate and interpret. ROI is also Versatile, Applicable to various scenarios, including financial investments, business projects, and marketing campaigns. And finally, it is a very helpful comparison tool that helps compare different investments scenarios.

While ROI is a useful metric, it has some limitations like ROI does not consider how long it takes to achieve the return. Two investments with the same ROI may have different time frames, which can affect decision-making. Another risk is that ROI Oversimplifies Complex Investments. For investments with many variables (e.g., external factors), ROI might not capture the full picture not account for the risk or uncertainty.

B. Blockchain

Blockchain is a type of distributed ledger technology (DLT) that records transactions in a secure, transparent, and tamper-resistant way. It consists of a decentralized network of computers (nodes) that work together to validate and record data in sequential "blocks" that are linked together to form a chain.

Blockchain has some key Characteristics. Those are:

- Blockchain is decentralized; it operates without a central authority. Data is stored and verified across a distributed network of nodes.
- Blockchain is immutable. Once data is added, it is impossible to alter without the consensus of the majority of nodes, ensuring data integrity.
- Transactions added on the blockchain are visible to all participants, making it highly transparent.
- Cryptographic techniques ensure the authenticity and security of the data.
- Blockchain uses consensus algorithms (e.g., Proof of Work) to validate transactions, ensuring trust without intermediaries.

Blockchain works like a waterfall. First there is a Transaction Initiation. Then the transaction is broadcast to the network and grouped in to blocks. Each block contains a hash of its data and the hash of the previous block, forming a chain, a cryptographic linking. Finally once validated, the block is added to the blockchain, and the transaction is complete (Gururaj et al. 2020).

There are various Types of Blockchain. Blockchain maybe Public, open to everyone (e.g., Bitcoin, Ethereum), or Private restricted to specific participants (e.g., enterprise solutions like Hyperledger) or even Consortium Blockchain, meaning Semi-decentralized

and governed by a group of organizations (e.g., banking systems).

Blockchain has already many applications like for Cryptocurrencies, Supply Chain Management (Tracks goods from origin to destination), Smart Contracts, Healthcare (Secure patient records and data privacy), Finance (secure payments and cross-border transactions) Voting Systems and more.

While Blockchain has many benefits, like Efficiency, Cost-Effectiveness (Cuts operational costs by automating processes) and Trust, there are also many challenges like: Scalability: High transaction volumes can slow down some blockchains. Energy Consumption: blockchains (e.g., Bitcoin) consume significant energy.Regulation: Governments are still developing frameworks for blockchain use.Adoption: Requires industry-wide collaboration for maximum impact.

C. Traceability

Traceability refers to the ability trace the history, location, and movement of a product, service, or process throughout its lifecycle. It ensures transparency and accountability by providing a clear record of where a product originated, how it was made or processed, and where it is at any given time.

Traceability can be towards upstream (Backward Traceability) where the origins of raw materials or components can be tracked, towards downstream (Forward Traceability) where a product can be tracked after it leaves its current stage and Internal Traceability where the movement of materials or components within an organization or production process can be tracked.

The importance of Traceability is quite high for any industry in terms of Quality Control, product recalls, building transparency and trust with consumers and other stakeholders and finally Sustainability for any company and organization (Dávila, A. et al 2021).

Applications of traceability can be found in several industries like Food Industry, where food items can be tracked from farm to table to ensure safety and quality, Pharmaceuticals which prevents counterfeit drugs and ensures compliance with regulations, Automotive industry where parts and components are tracked throughout manufacturing to improve safety and efficiency, Healthcare where medical devices and patient records are tracked to improve safety and accountability.

Technologies Enabling Traceability are Barcode and RFID Systems, Internet of Things (IoT) sensors that provide live updates on product location, condition, and environment, Blockchain and Enterprise Resource Planning (ERP) Systems.

The benefits of Traceability are easy to understand. Traceability helps companies to reduce waste and inefficiencies, protect consumers from unsafe products, increase operational efficiency and support sustainability initiatives and brand reputation and trust.

On the other hand, there are also many challenges concerning Traceability, like

- Cost: Implementing and maintaining traceability systems can be expensive.
- Complexity: Managing traceability across global supply chains with many stakeholders can be difficult.
- Data Integration: Requires effective integration of data from multiple sources

D. Blockchain in Traceability Systems

Blockchain in traceability systems enhances transparency, security, and efficiency in tracking and verifying the journey of products, services, or data across the stakeholders network. By leveraging blockchain technology, businesses can create a shared, tamper-proof record of transactions, enabling trust among all stakeholders (Song, J. et al 2019).

The benefits of Blockchain in Traceability can be summarized as follows:

-Block chain in Traceability can improve Transparency and Trust. Blockchain provides consumers and stakeholders with verifiable proof of a product's journey.

-Block chain in Traceability can enhance Food Safety. Blockchain helps track food items from farm to fork, enabling faster responses to contamination or recalls.

-Block chain in Traceability can prevent fraud by recording every step in the supply chain, blockchain reduces risks of counterfeiting and misrepresentation.

-Block chain in Traceability can save costs and improve efficiency. Automating processes and eliminating intermediaries reduces costs and speeds up supply chain operations.

Nevertheless, there are also challenges of using Blockchain for Traceability, like high Initial Costs because setting up blockchain infrastructure and integrating it with existing systems can be expensive. There might also be Data Standardization issues, since ensuring all supply chain participants follow consistent data formats is challenging. Also some blockchains struggle with high transaction volumes in large supply chains. Finally, the high energy consumption of some blockchain applications, might be also a barrier.

Blockchain in traceability systems can be “Fully automated” or “Semi Automated”. A fully automated blockchain for traceability integrates blockchain technology with automation tools like IoT devices, smart contracts, and AI to create an end-to-end traceability system that requires minimal human

intervention. The goal is to enhance efficiency, reduce errors, and ensure data integrity across supply chains or operational workflows.

Fully Automated Blockchain Traceability works by those steps: Data Collection, Data Validation and Storage, Process Automation with Smart Contracts, Analytics and Monitoring and End-to-End Visibility

Semi-automated blockchain for traceability combines blockchain technology with partial automation to track and manage supply chain activities. In this setup, certain processes, such as data collection or decision-making, involve manual input or human oversight, while other tasks, like data validation or execution of smart contracts, are automated.

This approach is suitable for businesses that may lack the infrastructure for full automation but still want the benefits of blockchain transparency and traceability.

E. ROI of Blockchain Traceability Systems

The Return on Investment (ROI) for blockchain traceability systems can vary significantly depending on the industry, implementation, and use case. However, businesses can generally expect a mix of direct and indirect benefits, ranging from cost savings to revenue growth and improved customer trust.

The main benefits of Blockchain Traceability are: Cost Savings, since Blockchain's immutability ensures data cannot be tampered with, reducing losses from fraud and data automated collection and sharing across the supply chain reduces manual effort and errors, improved Customer Trust and Risk Mitigation with minimizing Product Recalls and advanced Regulatory Compliance.

The Cost of a Blockchain Traceability Systems is the sum of the initial investment and the ongoing costs. The Initial Investment is the cost of Hardware and Software, the Integration Costs and the (e.g., ERP, IoT sensors) and the Training employees / partners and Change Management costs. The Ongoing Costs may be Transaction Fees, Maintenance and Updates costs and finally Energy Costs.

To calculate ROI for blockchain traceability systems, the below formula can be used:

$$ROI = \frac{\text{Gain from Investment (Revenue Increase + Cost Savings)}}{\text{Toral Costs}} \times 100$$

The steps to calculate ROI on those cases, besides quantifying the Benefits and Estimating the Costs, Time Horizon should also be considered since blockchain investments often yield higher returns over a longer time frame due to the gradual realization of benefits like reduced fraud or enhanced customer trust.

Return on Investment (ROI) for blockchain traceability systems is used in many cases in real life industry, like Food and Agriculture (e.g. Walmart's blockchain pilot with IBM reduced traceback time for mangoes from 7 days to 2.2 seconds, cutting potential recall costs significantly), Pharmaceuticals, Luxury Goods, Logistics and Supply Chain and others.

Nevertheless, there are challenges in calculating ROI for blockchain traceability systems, like Measurement Complexity, since benefits like customer trust and risk mitigation are hard to quantify, Adoption Challenges because ROI is maximized when all supply chain participants adopt the system (Ju, C. et al. 2022).

III. FINDINGS FROM OTHER RESEARCHERS

Any agri-food supply chain (AFSC) evolves in a competitive environment and more and more AFSCs use blockchain-based traceability services (BBTS). Research (Liu et al, 2022) has shown that blockchain-based traceability servicesplay a crucial role in the modern agri-food supply chain compared with any traditional traceability system that does not address the security and storage management challenges of information. So, more and more companies try to invest in BBTS for their AFSC.

In this research it is shown that when the decision makers want to invest in the blockchain-based traceability services, they should focus on their consumers perception about safety and quality for their agricultural products, and for the competitive products that are moved through the supply chain.

It is also found that investing in a blockchain-based traceability services increases the profits for all stakeholders in the supply chain. If the investment cost is high, investments reduce chain members' profits. Though "high cost" sounds subjective, it is not. The value to decide if the cost is high or not, is calculated as the sum of the cost of blockchain-based traceability services for a supplier and a retailer.

Other researchers point out that scalability issues blockchain-based traceability services in a supply chain should be addressed since blockchains are not suitable for storage of vast amounts of data (Casino, F.,et al.2020).

Even though ROI is used as a way to evaluate investments in blockchain, it is widely used in crypto currencies but not that much at blockchain-based traceability services in agri-food supply chain (Dasman, S. 2021; Li, R. 2023; Seabe, P. L., Moutsinga, C. R. B., &Pindza, E. 2024).

IV. Conclusions

From the literature review and the studied bibliography, it was found that Return on Investment is not widely used blockchain-based traceability services (BBTS) especially in the agri-food supply chain and in general. In the few cases that Return on Investment is used, it was found that even though the revenue increase from the adaptation of such a system is taken into account, the cost savings from the adaptation is neglected during calculations of the gain from the investment.

V. Limitations of Research and Further Research Proposed

The scope of the research may seem quite narrow, examining the Return on Investment for the Blockchain Traceability Systems in the food sector, but judging from the limited academic articles found, it seems that this issue is quite untapped by the researchers, in contrast to RoI of other Blockchain systems like crypto currencies. More on that, evidence of importance of calculation of RoI is found only for the agri-food sector and not for food in general, like ready meals etc. So, further research on the issue is suggested.

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