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Research Paper

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ANALYSIS OF FACTORS, ACTOR READINESS, AND STAKEHOLDER READINESS IN THE ADOPTION OF BLOCKCHAIN FOR MANGOSTEEN SUPPLY CHAIN TRACEABILITY

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ABSTRACT. Blockchain is currently a popular technology for ensuring data security and has the potential to be used across various sectors, especially in the supply chain. Traceability of information is an essential characteristic of blockchain in agricultural commodity supply chains, such as the mangosteen export supply chain, which faces challenges of a long distribution chain and a lack of digitization in the supply chain process, making traceability critical. The objectives of this study were to identify supporting and inhibiting factors and to assess the readiness of actors and stakeholders to adopt blockchain technology. Respondents were selected using purposive sampling, involving 19 key actors and stakeholders. Data were collected and analysed using the TRI method to measure the level of readiness to adopt blockchain technology. This study shows that the main obstacles identified include concerns about implementation and changes in work culture resulting from limited resources, regulations, and high implementation costs. Meanwhile, the main supporting factors are actors' awareness of the importance of digitization, the potential for transparent and efficient recording, and the ease of tracking. The level of readiness to adopt blockchain among mangosteen supply chain actors is moderate, with an average TRI score of 3.44.This category indicates that supply chain actors are beginning to adopt blockchain technology, but there are still obstacles to be addressed.

INTRODUCTION

Blockchain technology is currently a popular technology for ensuring data security, especially in the era of the 4.0 industrial revolution, which is driving technological development. Blockchain technology is a digital ledger that transparently records all activities within a network (Muray, 2019). This technology has great potential across sectors, including supply chains, because of its advantages in tracking product origins, quality, and the parties involved in the supply chain. These advantages explain how blockchain technology can increase consumer trust, business efficiency, and product quality (Usman *et al*., 2021). The advantages of blockchain in terms of transparency and traceability in the supply chain are key to building trust between partners and strengthening collaboration to address the challenges of a long distribution chain. One supply chain sector that is prone to product quality security issues and complexity is the horticultural commodity export sector (Hanafi *et al*., 2022).

According to the Performance Report of the Directorate General of Horticulture, Ministry of Agriculture (2024), the export performance of the horticulture sub-sector increased significantly by 12.57% in 2024. One of the 12 strategic commodities in the horticulture sub-sector is mangosteen, an exotic fruit native to Indonesia with the second-highest export value and a high export value in recent years (BPS, 2023). In Indonesia, mangosteen production in 2024 reached 4,167,526.62 quintals, with West Java contributing 1,001,168 quintals, making it the largest

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mangosteen producer in Indonesia and accounting for more than 14% of the total national production. Although mangosteen production in Indonesia is relatively high, exports remain low because many products do not meet export standards (BISIP, 2022). The main challenges for mangosteen, especially for the export market, include inconsistent fruit quality, a lack of a digital documentation system, and limited integration among supply chain actors (Ministry of Agriculture, 2024). These supply chain challenges make it increasingly urgent to have a reliable traceability system to meet export requirements, including product certification from the farm to the packaging house, such as good agricultural practice (GAP).

The government, through the Directorate General of Horticulture, has formulated an integrated strategy to develop leading horticultural commodities. One of the policy measures implemented is the digitization of agriculture, including quality standards, land and medicinal plant registration, and horticultural blockchain (Ministry of Agriculture, 2024). Although there is already a strategy for the development of leading horticultural commodities and a policy direction for agricultural digitization, blockchain technology remains relatively new to farmers, traders, and several institutions in the horticultural supply chain because of limited knowledge of digitization. This condition hinders the potential benefits of blockchain technology and its use in the field. Therefore, this study aims to identify the supporting and inhibiting factors for the adoption of blockchain technology and to assess the readiness of actors and stakeholders to adopt it in the mangosteen supply chain.

RESEARCH AND METHODS

This study was conducted in the Leuwiliang and Leuwisadeng subdistricts of West Java, involving 19 respondents selected through purposive sampling based on their experience and involvement in the mangosteen supply chain. Respondents included young and senior farmers, collectors, wholesalers, exporters, and relevant government representatives, thereby covering a variety of key roles and reducing the potential for selection bias. Purposive sampling is appropriate for exploratory research because it emphasizes the depth of information, flexibility, and a comprehensive understanding of phenomena that are rarely studied, as stated by Purba and Simanjuntak (2011), to explore ideas, find patterns, and build a theoretical foundation when the problem has not been clearly defined. Despite limitations such as small and non-random samples, this method remains important for obtaining the necessary contextual data. Primary data were collected through in-depth interviews, focus group discussions, and field observations. Secondary data were obtained from Statistics Indonesia, the Agriculture Office, BPP IV Leuwiliang, and scientific literature. The research stages included identifying the conditions of the mangosteen supply chain, designing dimensions and indicators, and assessing the readiness to implement blockchain technology using the technology readiness index (TRI).

Research Stages

Identification of the Condition of the Mangosteen Supply Chain in Leuwiliang and Leuwisadeng Districts

This research began with interviews and discussions to understand the existing supply chain conditions and identify the factors supporting and hindering the adoption of blockchain technology. The research was conducted through three main approaches: a literature review, field observation, and interviews. After collecting data from in-depth interviews on factors influencing adoption, the next step was to collect data by distributing questionnaires on the readiness of actors and stakeholders. The data processing analysis technique used the technology readiness index (TRI).

Determination of Dimensions and Attributes

This research instrument was developed by adapting the technology readiness index (TRI; Parasuraman, 2000) to the technology organization environment (TOE) framework. The indicators were formulated through a literature review and qualitative data analysis from in-depth interviews, focus group discussions (FGDs), and field observations. The qualitative data were organized to identify important statements and grouped into themes such as technological readiness, organizational barriers, perceived benefits, and environmental risks. Each theme was mapped to the TRI dimensions of optimism, innovativeness, discomfort, and insecurity so that each item in the quantitative questionnaire was based on actual qualitative findings in the field. Factors with positive views were categorized as optimism and innovativeness, while factors reflecting barriers or concerns were categorized as discomfort and insecurity.

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The final instrument consisted of 32 items using a 1–5 Likert scale, which was a simplified version of the original TRI items and was adapted to the context of blockchain adoption based on qualitative findings and supporting literature. The validation process was conducted by experts, including academics and practitioners, who evaluated the clarity, relevance, and contextual suitability. Suggestions and input from experts were adjusted for the final questionnaire used to collect research data.

The mapping of the technology-organization-environment (TOE) and technology readiness index (TRI) components was conducted systematically based on the literature. Each TOE variable was allocated to a TRI dimension (optimism, insecurity, and discomfort) based on the perceived characteristics being assessed. A total of 32 survey items were identified: 13 measuring optimism, nine measuring insecurity, and eight measuring discomfort, as shown in Table 1.

Assessment of the Readiness of Actors and Stakeholders for Blockchain Technology Adoption.

Assessment of actors' and stakeholders' readiness was conducted using Microsoft Excel, with a Likert scale of 1–5 for each statement. The conversion of Likert responses to readiness scores followed the TRI weighting procedure by Parasuraman (2000).

Table 1. Mapping technology-organization-environment (TOE) with technology readiness index (TRI)

TOE	Variables	TRI Dimension	Definition
Technology	Technology Readiness & Suitability	Optimism	Belief that technology brings benefits and is accessible.
	Digital Readiness & Infrastructure	Discomfort	Concerns about technical complexity and security.
	Transparency	Optimism	Perception that blockchain improves data clarity.
	Perceived Benefits	Optimism	Expectations of increased efficiency and added value.
Organizational	Business Process Compatibility	Optimism	The belief that technology is compatible with existing processes.
	Implementation Complexity	Discomfort	The perception that technology is difficult to understand and requires major changes.
	Scalability & Structural Readiness	Insecurity	Uncertainty about the organization's capacity to develop technology.
	Implementation Costs	Insecurity	Financial risk and investment uncertainty.
	Human Resource Readiness & Knowledge	Insecurity	Skepticism about internal technical capabilities.
	Management Support & Innovation Culture	Optimism	Internal commitment to drive adoption.
	Organizational Learning Capability	Optimism	Willingness to participate in training and adapt to new technologies.
Environmental	Government Regulations & Policies	Insecurity	Uncertainty in regulations and formal support.
	Government Incentives & Support	Insecurity	Skepticism about the sustainability of external assistance or facilities.
	Competition & Market Competitive	Optimism	Blockchain is seen as an opportunity to increase competitiveness.
	Partner & Ecosystem Support	Insecurity	Uncertainty about partners' interest in participating.
	Environmental & Security Risks	Insecurity	Concerns about cybersecurity and potential losses.
	Organizational Adoption Intention	Optimism	Willingness to adopt technology when the ecosystem is supportive.

Sources: Al-Ashmori *et al*., 2023; Dehghani *et al*. 2022; Grida *et al*., 2022; Khan *et al*., 2023; Lustenberger *et al*., 2021; Noor, 2022; Malik *et al*., 2021; Rijanto, 2021; Trpkov *et al*., 2024; Zheng *et al*., 2023.

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Each TRI dimension (optimism, innovativeness, discomfort, and insecurity) had a total weight of 25%, so the weight of each item was calculated as 25% divided by the number of items in that dimension. Statement values were calculated using the following formula:

Statement weight: $\frac{25\%}{\Sigma \text{ Statement variables}}$

Statement value: $\frac{\Sigma \text{ (Number of answers x answer score)}}{\text{Number of Respondents}}$ x Statement Weight

Variable value = ∑ statement value
TRI value = ∑ variable score

The value for each dimension is obtained from the sum of all statement values in that dimension, and the total TRI score is the accumulation of the four dimensions. Optimism and innovativeness are enablers that strengthen readiness to adopt technology, whereas discomfort and insecurity reduce readiness. Optimism and innovativeness are factors that drive the technology adoption process, whereas discomfort and insecurity act as barriers in the technology adoption process, as shown in Figure 1.

RESULTS AND DISCUSSIONS

Overview of the Mangosteen Supply Chain in Leuwiliang and Leuwisadeng Districts

In the Leuwiliang and Leuwisadeng subdistricts follows a pattern similar to that of farmers, collectors, packers, exporters, and destination countries. Farmers are the primary producers, mostly smallholders, who manage mangosteen plantations (Sayekti *et al.*, 2014). Collectors act as intermediaries between farmers and downstream actors, playing an important role in collection, quality assessment, and sales to partner companies, while facing infrastructure constraints and risk perceptions in their operations (Pratiwi *et al.*, 2022; Fauziana *et al.*, 2024). In the next stage, wholesalers distribute mangosteen to broader markets but often face constraints in the availability of export-quality fruit (Narakusuma *et al.*, 2013). Packing houses serve as the final quality control point before export, through a process of sorting and verification of good agricultural practices (GAP) certification. Downstream, exporters not only guarantee product safety but also act as strategic partners for farmers in supply chain development (Pratiwi *et al.*, 2022). In this study, exporters see blockchain technology as an opportunity to improve transparency in quality standards throughout the supply chain (Sayekti *et al.*, 2023).

The mangosteen supply chain, dominated by small businesses, means that the current recording of origin by businesses, whether small or large collectors, is still done manually. The records relate only to the quantity and price of mangosteen in the form of receipts. Large traders and packaging houses currently keep records in Microsoft Excel, but there is no integrated digital system for recording. This condition shows the low level of traceability in the mangosteen supply chain in the sub-districts of Leuwiliang and Leuwisadeng. According to Yursiana and Jaya (2022), a traceability system that is implemented solely manually (conventionally) through daily manual bookkeeping in a production system is undoubtedly very difficult to maintain as production volume and marketing coverage grow.

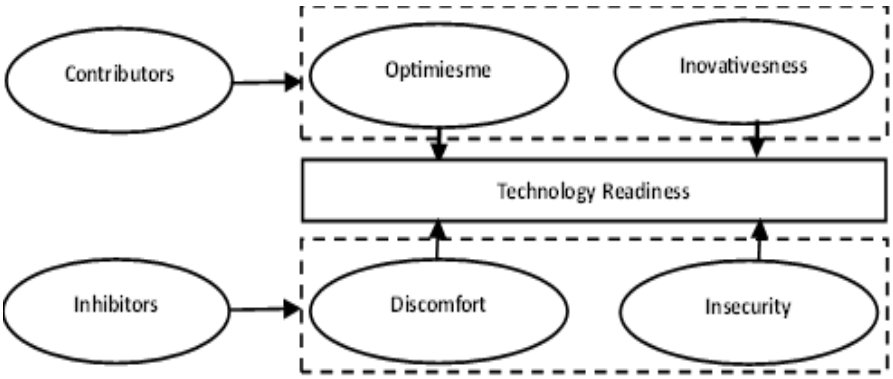

Figure 1. Technology Readiness Index Theory (TRI), Parasuraman (2000)

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Recording the origin of mangosteen is important to minimize losses in the event of mangosteen returns from the destination country. In 2020, mangosteen returns were received from an importing country by the Manggis Raya Lestari farmer group. After mangosteen arrived in China, it was found not to meet the applicable requirements; therefore, 3,000 baskets were returned to Indonesia. This caused losses to traders because the origin of the problematic mangosteen could not be identified. This finding aligns with the research by Putra and Labasayani (2022), who state that traceability is an important requirement in international trade, including the provision of supporting documents on the origin of products required for export, thereby helping to meet global regulatory requirements. The lack of proper record-keeping at every stage of the supply chain, especially at the upstream level, poses an initial challenge for implementing blockchain technology, which requires integrated data.

Factors Influencing the Adoption of Blockchain Technology in the Mangosteen Supply Chain

In-depth interviews with actors and stakeholders in the mangosteen supply chain in Leuwiliang and Leuwisadeng revealed the factors that hinder and support the adoption of blockchain technology, as illustrated in the rich picture (Figure 2).

The adoption of blockchain technology in the mangosteen supply chain is not merely a technological issue but involves the complexity of a multi-stakeholder ecosystem. Pradana *et al.* (2024) research confirms that readiness for blockchain adoption goes beyond technical considerations and requires in-depth attention to potential users and various actors in the supply chain. A RPA reveals the many diverse factors that influence the adoption of blockchain technology among actors in the mangosteen supply chain and also shows a significant gap between export market needs (which demand an integrated system with full traceability) and upstream readiness (farmers and collectors), which is relatively weak in terms of digital capabilities. According to Akella *et al*. (2023), the knowledge gap and inconsistent information among parties undermine trust and reliability in the adoption of blockchain technology, indicating that, in this context, the ecosystem gap is not only technical but also concerns incentives, regulations, and misaligned capacities.

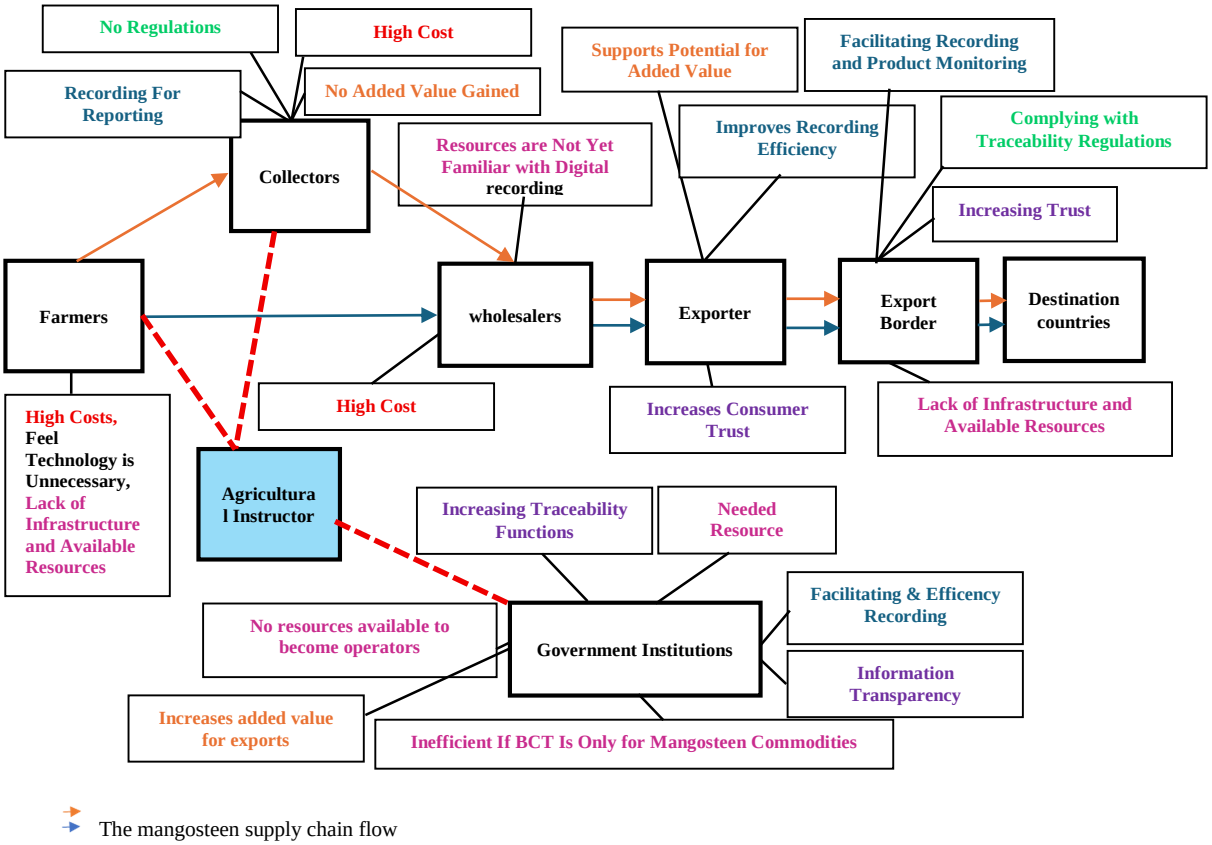

Figure 2. Rich picture of the mangosteen supply chain and factors affecting blockchain adoption

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The research findings indicate that the innovation dimension is the main factor in the TRI method assessment, with a total weight of 0.269. This weight is derived from the contributions of statements in the innovation dimension, with the highest weight recorded at 0.296, indicating that innovation has the most significant impact on readiness to adopt blockchain technology. Respondents identified two main benefits. The first is increased transparency of information in the supply chain, with a weight of 0.121 (12.1% of the total value of statements in the optimism dimension). Respondents believe that blockchain can produce a more transparent recording system that is easily accessible to all parties in the supply chain. This finding indicates that transparency is the most desirable benefit, especially given the increasingly stringent international export regulations. Second, respondents see that blockchain can provide a competitive advantage, with a weight of 0.109. Stakeholders believe that the use of blockchain will strengthen their position in the agricultural product tracking system market and provide greater opportunities to explore export markets. In addition to these perceived benefits, actors in the supply chain also showed a strong desire to adopt new technologies, with a weight of 0.269, which is the highest value among all innovation sub-dimensions. Supply chain actors showed a high willingness to try new technologies. This is the highest weight among all sub-dimensions, indicating that the intrinsic motivation and determination of actors, as described by Zhang *et al.* (2025), are the most significant factors influencing readiness to adopt blockchain TRI analysis shows that inhibiting factors contribute significantly to balancing driving factors. Two main inhibiting factors were identified: discomfort and uncertainty. From the discomfort dimension, with a statement weight of 0.289, this weight is derived from the statement value for concerns related to implementation. This indicates the need for training for human resources in the view of farmers and collectors that the transition from manual to digital systems requires a significant investment in human resource development, as most actors still apply manual documentation practices; hence, significant changes in work procedures are considered an additional burden (Yogarajan, 2023). Additionally, implementing blockchain requires adjustments to work practices and a redefinition of responsibilities within the organization (0.139). This weight reflects serious concerns that the implementation of technology will alter existing organizational dynamics, leading to significant cultural resistance.

Furthermore, from a security perspective, external risks and regulations are barriers to the implementation of blockchain technology (Choi *et al.,* 2020). Current regulations do not support the implementation of blockchain, with a statement weight of (0.123) from TRI. Regulatory uncertainty is a significant obstacle. Research by Malik *et al.* (2021) emphasizes that government support, in the form of a clear regulatory framework, has a significant positive impact on the adoption of blockchain technology. In contrast, the absence of clear regulations or standards hinders its implementation. In addition, concerns about the potential for technology hacking (0.106) are a barrier to the adoption of blockchain technology. Although blockchain is known for its security, perceptions of cybersecurity risks remain a significant obstacle, especially among less experienced actors in digital systems.

Assessment of Readiness for Blockchain Technology Adoption to Enhance Mangosteen Supply Chain Traceability

In Indonesia, the horticultural commodity supply chain, particularly for mangosteen, is generally dominated by farmers and small- to medium-sized entrepreneurs. This condition creates resistance to the adoption of digital technologies, such as blockchain technology, particularly in terms of financial readiness, human resources, and technical readiness. This assessment of adoption readiness uses the TRI method, which has four assessment dimensions: optimism, innovation, discomfort, and insecurity. Supporting and inhibiting factors can be identified from the questionnaire scores, providing an overview of aspects that could encourage or inhibit the adoption of blockchain technology.

Overall, the assessment of readiness to adopt blockchain technology in the mangosteen supply chain shows optimism and innovation scores of 0.90 and 0.89, respectively, indicating that some stakeholders with a more advanced vision are open to adopting the technology and have high expectations for its benefits. However, there is also a relatively high level of discomfort and insecurity (0.87 and 0.78). This difference indicates a gap in psychological and practical readiness, as well as between expectations and reality in the field. The almost identical values across dimensions indicate a similar difference in attitudes towards blockchain technology (Akella *et al.,* 2023). Respondents showed strong enthusiasm for the potential and benefits of blockchain technology but also had significant concerns. The total score for the

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assessment of blockchain technology adoption readiness across all actors in the mangosteen supply chain was 3.44, indicating a moderate level of readiness. This category indicates that supply chain actors are beginning to adopt blockchain technology; however, obstacles remain to be addressed. This was also found in Kamble *et al*. (2019) study on blockchain in supply chains in India, where, despite high interest and optimistic attitudes among organizations, concerns remained about the security and complexity of blockchain technology.

The research findings show diversity in the readiness of the blockchain ecosystem in the mangosteen supply chain among the actors. At the upstream level, farmers and collectors experience low readiness due to limited digital capacity, lack of infrastructure, and the view that digital recording increases workload without any incentives. Appropriate change efforts at this level include basic training, simplification of recording applications, and volume- or quality-based incentives that encourage consistent recording (Khan *et al*., 2022). Local governments, farmer organizations, and private actors from the export side can play an important role in promoting initial preparation. At the intermediate level, collectors and processors, as well as local governments, show moderate readiness with a reasonably high willingness to adopt, but still face obstacles such as business process adjustments, system integration with existing practices, and operational transition costs. Initial steps related to system integration support, the creation of new standard operating procedures) SOPs), and cost-sharing models can help digitize record-keeping (Martina *et al*., 2024). The role of trader organizations and relevant ministries is crucial in supporting the regularity of the process. At the downstream level, exporters and global buyers are well prepared, with the main requirements being regulatory compliance, cross-border system compatibility, and data standardization. This can begin with the formulation of a collaborative regulatory framework and the development of integrated data standards under the leadership of the Ministry of Agriculture and inter-country authorities. This was confirmed by the research of Malik *et al*. (2021), who stated that clarity of rules increases confidence in technology adoption.

The success of blockchain technology adoption is determined not only by technological maturity but also by the ecosystem that supports it. The readiness of the ecosystem depends on each actor's ability to carry out their intervention roles in a coordinated manner, thereby progressively minimizing specific obstacles at each level (Lustenberger *et al*., 2021). High levels of insecurity and discomfort serve as an important reminder, revealing that business actors and stakeholders are well aware of the many challenges that may arise in adopting blockchain technology, which is a first step towards better preparation for adoption. The implementation of blockchain technology can be carried out gradually with government support and private-sector involvement. The government offers subsidies for key infrastructure, while the remaining financing needs are met through a cost-sharing scheme (Vikaliana *et al*., 2021). Training programs can reach more than half of the target population in priority areas, and basic regulations on the use of blockchain are issued after a lengthy policy-making process. At the same time, more innovative exporters provide higher price incentives to encourage the early participation of actors in the supply network. This situation maintains the stability of the innovation element and the desire to adopt, while obstacles related to human resource training and regulatory uncertainty begin to diminish. However, organizational-level obstacles remain, as the adoption process is still selective. (Vikaliana *et al*., 2021).

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

The adoption of blockchain technology to improve the traceability of the mangosteen supply chain is influenced by various factors related to technology, organization, and the environment. The main obstacles are stakeholder concerns, technical and financial capabilities, and organizational policies, regulations, or government support. Meanwhile, the most prominent supporting factors include technological innovation and its benefits (traceability and transparency). The readiness of actors and stakeholders to adopt blockchain technology is currently moderate, with a total TRI value of 3.44. However, to increase adoption readiness, perceptions of discomfort and insecurity need to improve. Research on assessing blockchain adoption readiness should be conducted continuously to monitor the development of organizational or system readiness for adopting blockchain technology.

Recommendations

This approach allows for the early identification of needs and challenges, while also serving as a basis for formulating appropriate and effective actions or strategies to overcome problems that arise in the field and improve current readiness.

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