E-ISSN : 2686-6331
P-ISSN : 2686-6358
DINASTI INTERNATIONAL JOURNAL OF EDUCATION MANAGEMENT AND SOCIAL SCIENCE (DIJEMSS)
DINASTI PUBLISHER
https://dinastipub.org/DIJEMSS dinasti.info@gmail.com +62 811 7404 455
DOI: https://doi.org/10.38035/dijemss.v5i6
Received: 12 July 2024, **Revised:** 9 August 2024, **Publish:** 10 August 2024

Blockchain Technology's Impact on Port Logistic Operational Enhancement at Pontianak Port

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Abstract: This study investigates the impact of blockchain technology on port logistics operations at Pontianak Port, West Kalimantan, Indonesia. Despite recent infrastructure developments, such as the Kijing Terminal, the port faces significant operational challenges, including inadequate traceability, incomplete real-time cargo information, and a lack of transparency. These issues lead to inefficiencies and mistrust among stakeholders, negatively impacting the port's reliability, operational effectiveness, and customer satisfaction. The research employs a structured quantitative design, surveying 110 participants involved in port operations, to examine the influence of traceability, transparency, and transaction efficiency on blockchain technology adoption and subsequent service quality improvements. Data analysis using SmartPLS 4.0 software confirms that enhanced traceability, transparency, and efficient transaction processes significantly impact the adoption of blockchain technology, which in turn significantly improves service quality. The study highlights the potential of blockchain to address these deficiencies and suggests future research to explore broader samples, additional influencing factors, and longitudinal studies.

Keyword: Blockchain, Traceability, Transparency, Service Quality, PLS-SEM Analysis.

INTRODUCTION

The Port of Pontianak, an essential hub in West Kalimantan, Indonesia, is pivotal to the regional economy. Despite recent infrastructure developments, such as the inauguration of the Kijing Terminal, which boasts a capacity of 500,000 TEUs and 8 million tons of non-containerized cargo annually, the port faces significant operational challenges. These challenges include inadequate traceability, incomplete real-time cargo information, and a lack of transparency, leading to inefficiencies and mistrust among stakeholders. These inefficiencies and trust issues compromise the port's reliability, operational effectiveness, and customer satisfaction, thus negatively impacting the port's service quality and reputation.

Digitalization and automation of processes are essential to improve operational efficiency. Integrated information systems have been implemented in various ports to support logistics management. Traditional ICT-based port logistics systems follow a centralized architecture to host and process data and services (Aggarwal, 2016). However, centralized logistics systems fail to ensure security, real-time data access, operational visibility, and trust among participating organizations.

Therefore, selecting advanced and appropriate ICT applications is crucial to address these deficiencies. The requirement for applications capable of providing enhanced traceability, transparency, and transaction efficiency is paramount, as these capabilities can ultimately improve operational performance, enhance transparency and traceability, and significantly increase service quality. Studies have indicated that the integration of blockchain technology in port operations can address these deficiencies by offering immutable records and real-time data sharing (Ashraf Shirani, 2018; Siyavash Filom & Edwin van Hassel, 2020). However, limitations such as technical issues, ongoing industry thefts, public perception, government regulations, and the adoption rate of new technology must be considered (Huang et al., 2019; Liu & Wu, 2020). Previous researchers have extensively suggested the implementation of applications to solve issues at the port based on the related literature on port issues. These studies focus on traceability(X1)(Ahmad et al., 2021), enabled transparency(X2)(King Boison & Antwi-Boampong, 2020; Rejeb, 2020), optimization of transaction processes(X3) (Bavassano et al., 2020; Henesey et al., 2019; Nasih et al., 2019), others focus on blockchain technology (Z) (Agarwal, 2018; Cole et al., 2019; Kouhizadeh et al., 2021; Longo et al., 2020)) and evaluating service quality (Y) (Kolanović, 2011; Lee et al., 2018; Tae YEO et al., 2015; Ugboma et al., 2007).

Despite these challenges, the potential benefits of digitalizing port management systems to enhance service quality and operational efficiency remain significant and warrant further empirical investigation. To systematically explore these aspects, the following hypotheses have been formulated for this study: H1: Traceability significantly impacts the adoption of blockchain technology; H2: Transparency significantly impacts the adoption of blockchain technology; H3: Efficient transaction processes significantly impact the adoption of blockchain technology: H4: The adoption of blockchain technology significantly impacts service quality: H5: Traceability significantly impacts service quality: H6: Transparency significantly impacts service quality: H7: Efficient transaction processes significantly impact service quality: H8: Traceability indirectly and significantly impacts service quality through blockchain technology: H9: Transparency indirectly and significantly impacts service quality through blockchain technology: H10: Efficient transaction processes indirectly and significantly impacts service quality through blockchain technology.

Operational definitions help researchers achieve a measurement tool aligned with the nature of the variables defined in the research concept. For this study, the following operational definitions are used:

1. Traceability (X1): The ability to trace the history, application, or location of an entity by means of recorded identification. In port operations, traceability refers to the capability to track cargo movements and operations accurately and reliably(Kupriyanovsky et al., 2018).
2. Transparency (X2): The quality of being easily seen through or detected. In the context of port logistics, transparency involves clear, accessible, and understandable information flow among all stakeholders, minimizing misinformation and enhancing trust (King Boison & Antwi-Boampong, 2020).
3. Transaction (X3): The effectiveness with which transactions are conducted, minimizing time, cost, and errors. Efficient transaction processes are critical in managing the large volumes of data and operational demands of port logistics (Bavassano et al., 2020).

4. Blockchain Technology (Z)**:** A decentralized digital ledger technology that ensures secure, transparent, and tamper-proof data recording and sharing. In port operations, blockchain can enhance traceability, transparency, and transaction efficiency (Agarwal, 2018; Kouhizadeh et al., 2021).
5. Service Quality (Y)**:** The overall assessment of a service by its customers, which includes factors such as reliability, responsiveness, assurance, empathy, and tangibles. High service quality is essential for customer satisfaction and operational effectiveness in port logistics (Kolanović, 2011; Lee et al., 2018; Tae YEO et al., 2015; Ugboma et al., 2007).

METHOD

This study employs a structured quantitative research design to examine the impact of traceability, transparency, and transaction processes on blockchain technology adoption in port operational management and its subsequent effect on service quality at Pontianak Port. The research focuses on stakeholders involved in port operations at Pontianak Port. Data were collected from a sample of 110 participants, including port managers, logistics managers, and other stakeholders directly involved in port operations. The study was conducted over a period from Dec 2023 to Jan 2024 at the operational terminal of the Port of Pontianak, West Kalimantan.

Data were gathered using structured questionnaires designed to capture information on the level of traceability in current port operations, the transparency of operational processes, the efficiency of transaction processes, the adoption and integration of blockchain technology, and the quality of services provided at the port. Secondary data were also collected from existing literature, port operation reports, and relevant studies on blockchain technology in logistics and supply chain management.

The research followed a systematic procedure, beginning with data collection through the distribution of structured questionnaires to participants and the compilation of secondary data from credible sources. The collected data were then processed using SmartPLS 4.0 software for Structural Equation Modeling (SEM).

RESULTS AND DISCUSSION

Validity dan Reliability

Based on the output calculated from the PLS Algorithm as shown in Table 1, it can be explained as follows: the AVE values are all greater than or equal to 0.5. The Cronbach's alpha values for each variable are less than or equal to the rho_a values, and the Cronbach's alpha values are less than or equal to the rho_c values. According to (Hair et al., 2017). it can be stated that all constructs are reliable. Therefore, the measurement of the outer model structure in this study is acceptable, allowing the research to proceed. The results of the Discriminant Validity test using HTMT show HTMT values < 0.9 as shown in Table 2. This meets the measurement requirements for the constructs in this study. The correlation values of the construct measurement items have higher associations compared to other constructs. Therefore, it can be declared that the model possesses good discriminant validity

Tabel-1 Validity and Reliability Test

Variable	Cronbach's alpha	Composite reliability rho_a	Composite reliability rho_c	AVE
Traceability	0.882	0.889	0.914	0.682
Transparency	0.874	0.88	0.908	0.665
Transaction	0.875	0.876	0.914	0.727
Blockchain	0.771	0.772	0.853	0.592
Service Quality	0.8	0.81	0.87	0.625

The structural model illustrates the causal relationships between latent variables (constructs) and is evaluated using path coefficients and their significance levels. The results processed using SmartPLS can be visually observed in Figure 1, which illustrates the relationships between constructs, their path coefficients, and the significance values based on the t-statistics.

Tabel-2 Discriminant Validity: Heterotrait-Monotrait Ratio (HTMT)

	Variable	X1	X2	X3	Y	Z
X1	Traceability					
X2	Transparency	0.825				
X3	Transaksi	0.686	0.686			
Y	Service Quality	0.792	0.777	0.732		
Z	Blockchain	0.733	0.764	0.673	0.838	

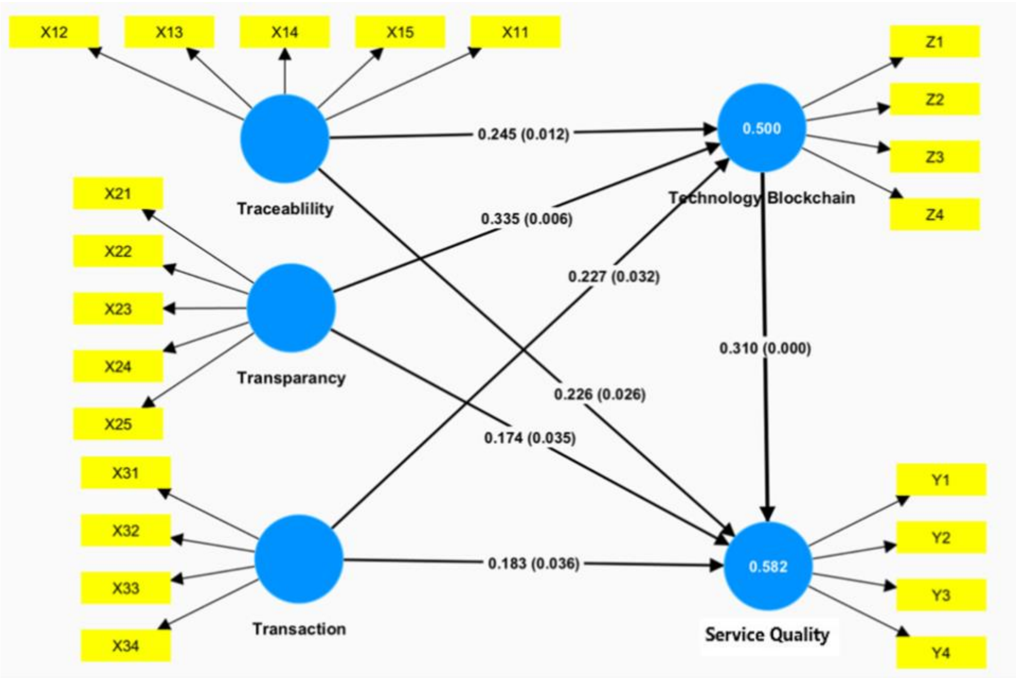

Figure 1 Inner Model Structure

Hypothesis Testing

Hypothesis testing using statistical values, with an alpha level of 5%, the T-statistic value utilized is 1.96. Consequently, the criteria for accepting or rejecting the hypothesis are as follows: the alternative hypothesis (Ha) is accepted, and the null hypothesis (Ho) is rejected if the T-statistic is greater than 1.96 and the P-value is less than 0.05 (Hair et al., 2017) Based on the analysis of the direct hypothesis testing results displayed in Table-3 and indirect hypothesis testing results displayed in Table-4.

Table-3 Direct Hypothesis Testing

Path	Original sample	Sample mean	Std deviation	T statistics	P values
Traceability -> Technology Blockchain	0.245	0.258	0.096	2.542	0.012
Transparency -> Technology Blockchain	0.335	0.324	0.119	2.806	0.006
Transaction -> Technology Blockchain	0.226	0.228	0.1	2.261	0.026
Technology Blockchain -> Service Quality	0.31	0.305	0.085	3.637	0
Traceability -> Service Quality	0.227	0.223	0.105	2.167	0.032
Transparency-> Service Quality	0.174	0.172	0.081	2.142	0.035
Transaction -> Service Quality	0.183	0.191	0.086	2.123	0.036

Tabel-4. Indirect Hypothesis Testing

Path	Original sample	Sample mean	Std deviation	T statistics	P values
Traceability -> Technology Blockchain -> Service Quality	0.076	0.078	0.038	2.011	0.047
Transparency -> Technology Blockchain -> Service Quality	0.104	0.1	0.049	2.123	0.036
Transaction -> Technology Blockchain -> Service Quality	0.07	0.069	0.035	1.996	0.048

Discussion

Hypothesis H1 shows that traceability positively and significantly affects blockchain technology, consistent with previous studies (Nasih et al., 2019). Blockchain's decentralized nature provides immutable records crucial for port logistics, enhancing traceability features (Anwar et al., 2019).

Hypothesis H2 indicates that transparency positively and significantly affects blockchain technology. This supports the need for transparent real-time information exchange in port operations (Ahmad et al., 2021). Blockchain enhances trust and reduces errors and fraud in logistics (Centobelli et al., 2022).

Hypothesis H3 shows that transactions positively and significantly affect blockchain technology. Blockchain enables secure, fast, and immutable transaction records, essential for managing large data volumes in logistics (Anwar et al., 2019; Henesey et al., 2019). This reduces processing time and costs, improving operational efficiency (Viriyasitavat et al., 2020).

Hypothesis H4 indicates that blockchain technology positively and significantly affects service quality. Blockchain provides accurate and real-time information, enhancing logistics management and reducing service disruptions (Sun et al., 2018).

Hypothesis H5 shows that traceability positively and significantly affects service quality. Traceability allows efficient tracking of goods and documents, which is crucial for managing complex port logistics and improving customer satisfaction (Sánchez-Franco et al., 2019)

Hypothesis H6 indicates that transparency positively and significantly affects service quality. Blockchain provides open access to data, improving operational transparency and decision-making (Centobelli et al., 2022; Pakurár et al., 2019)

Hypothesis H7 shows that transactions positively and significantly affect service quality. Blockchain improves transaction efficiency and security, enhancing logistics management and customer satisfaction (Ahimbisibwe et al., 2016)

Hypothesis H8 indicates that traceability indirectly and significantly affects service quality through blockchain. Blockchain supports high-quality standards and improves service consistency and accountability (Dutta et al., 2020; Salah et al., 2019)

Hypothesis H9 shows that transparency indirectly and significantly affects service quality through blockchain. Blockchain enhances trust and collaboration among stakeholders, improving service quality (Centobelli et al., 2022; Sander et al., 2018).

Hypothesis H10 indicates that transactions indirectly and significantly affect service quality through blockchain. Blockchain supports reliable and cost-effective transaction management, enhancing service quality (Viriyasitavat et al., 2020).

CONCLUSION

This study aimed to assess the impact of blockchain technology on port logistics operations at Pontianak Port, testing a series of hypotheses regarding traceability, transparency, transaction efficiency, and service quality.

1. Traceability significantly impacts the adoption of blockchain technology.
2. Transparency significantly impacts the adoption of blockchain technology.
3. Efficient transaction processes significantly impact the adoption of blockchain technology.
4. The adoption of blockchain technology significantly impacts service quality.
5. Traceability significantly impacts service quality.
6. Transparency significantly impacts service quality.
7. Efficient transaction processes significantly impact service quality.
8. Traceability indirectly and significantly impacts service quality through blockchain technology.
9. Transparency indirectly and significantly impacts service quality through blockchain technology.
10. Efficient transaction processes indirectly and significantly impact service quality through blockchain technology.

The findings of this study have several implications: the study provides practical insights for port management and policymakers to enhance blockchain adoption and improve service quality. Policymakers need to develop supportive regulations, provide incentives for technology adoption, strengthen related institutions, and ensure infrastructure availability to facilitate blockchain implementation. The study contributes to the literature by confirming the significant roles of traceability, transparency, and transaction efficiency in blockchain adoption and their impact on service quality.

This study has some limitations: 1) The sample is limited to respondents from Pontianak Port, which may not be representative of other ports or regions; 2) The study focuses on specific aspects of blockchain technology, and other potential factors were not explored and 3) The research is cross-sectional, providing a snapshot in time without examining changes over time.

Future research should address these limitations and further explore: 1) Including more ports and regions to generalize findings; 2) Investigating other factors that may influence blockchain adoption and service quality; 3) Conducting longitudinal research to observe changes and trends over time; 4) Comparing the impact of blockchain technology in different logistics and supply chain contexts.

By addressing these areas, future studies can build on the current research, providing deeper insights into the adoption and impact of blockchain technology in logistics and port operations.

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