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Blockchain Implementation Readiness in Enterprise Digital Transformation: A Socio-Technical Capability Perspective

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ABSTRACT

Objective: This study develops a socio-technical model regarding blockchain implementation readiness by extending the *Technology-Organization-Environment* (TOE) framework to include aspects of process maturity and human capabilities. It addresses the limited understanding of whether organizations possess the necessary capabilities to transition from a mere intention to adopt blockchain to actual implementation readiness.

Methods: Survey data were collected from 101 professionals involved in corporate digital transformation and analyzed using Partial Least Squares Structural Equation Modeling (PLS-SEM). The measurement model was evaluated for reliability and convergent validity prior to testing the proposed structural relationships.

Results: Environmental capability is a significant direct predictor of implementation readiness ($\beta = 0.262$; $p = 0.005$). Technological capability significantly strengthens process maturity ($\beta = 0.241$; $p = 0.032$), whereas technological, organizational, process, and human capabilities do not significantly influence readiness. The positive influence of technology, mediated by process maturity ($\beta = 0.046$), suggests a potential capability development pathway, although further inferential testing is required. The model explains 13.1% of the variance in implementation readiness.

Conclusion: Blockchain implementation readiness is an ecosystem-dependent socio-technical capability rather than merely the result of technology investment. External alignment and process transformation are crucial in preparing organizations for blockchain implementation.

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1. Introduction

Enterprise digital transformation increasingly depends on technologies that coordinate data, decisions, and transactions across organizational boundaries. Artificial intelligence, cloud computing, the Internet of Things, and blockchain can integrate processes, improve operational visibility, and support real-time decisions (Kraus et al., 2023; Verhoef et al., 2021). Blockchain is distinctive because it can establish decentralized trust, preserve data integrity, and enable secure exchange among firms (Casino et al., 2019; Al-Jaroodi & Mohamed, 2019). Yet enterprise projects often stall after the adoption decision because technical access does not guarantee integration, governance, user capability, or partner participation. This implementation gap creates both a theoretical problem—adoption models do not fully explain operational preparedness—and a managerial problem, because firms may invest before the surrounding capabilities are ready. Most blockchain studies use the Technology–Organization–Environment (TOE) framework to explain adoption decisions or intentions (Orji et al., 2020). This literature leaves three connected gaps. First, adoption intention captures willingness to use blockchain, whereas implementation readiness captures the capability to deploy, integrate, govern, and sustain it. Second, broad measures of organizational readiness often combine strategy, processes, and people, making it difficult to identify where implementation bottlenecks arise. Third, direct-effect models provide a limited insight into how technological resources become operationally useful. These gaps matter because enterprise transformation depends on complementary capabilities and cross-firm coordination rather than on isolated technology ownership (Treiblmaier, 2018).

This study addresses these gaps by conceptualizing blockchain implementation readiness as a socio-technical organizational capability. The model integrates technological, organizational, environmental, process, and human constructs, tests their direct relationships with readiness, and examines whether process maturity transmits the effect of technological capability. Readiness is therefore treated as the capacity for implementation, not as a favorable attitude toward adoption. This study contributes in three ways. It defines a theoretically sharper boundary between adoption intention and implementation readiness; separates process maturity and people capability from the strategic and resource-based content of organizational capability; and evaluates an extended TOE model while explicitly tempering claims to match the model's explanatory power and the study's exploratory design.

The model was evaluated using PLS-SEM on survey data from professionals involved in enterprise digital transformation. The study addresses the following research questions:

RQ1. Which socio-technical capabilities directly influence blockchain implementation readiness in enterprise digital transformation?

RQ2. How do process maturity and people capability extend the TOE framework, and does process maturity transmit the effect of technological capability on readiness?

RQ3. What does a capability-based socio-technical model reveal about blockchain implementation readiness in intelligent enterprise ecosystems?

2. Literature Review

2.1 Blockchain Implementation Readiness in Enterprise Digital Transformation

Scalability, governance complexity, and partner coordination (Hughes et al., 2019). These challenges indicate that implementation depends on more than technical infrastructure. Blockchain implementation readiness is therefore defined here as an organization's capability to deploy, integrate, govern, and sustain blockchain-enabled processes. Unlike adoption intention, which reflects willingness or a decision to adopt, readiness concerns the capabilities required after that decision is made. This distinction is especially important in inter-organizational settings, where implementation depends on both internal preparedness and ecosystem alignment.

2.2 Technology–Organization–Environment Framework

Cross-organizational coordination is central to blockchain implementation. TOE therefore provides the minimum cross-level structure needed to study enterprise blockchain, while the socio-technical extension addresses capabilities

that conventional adoption models tend to aggregate. Despite its usefulness, conventional TOE research has two limitations for explaining implementation readiness. It commonly models adoption as a discrete decision and estimates independent net effects, offering a limited explanation of post-adoption capability development. It also produces inconsistent findings: technological capability is prominent in some settings, whereas ecosystem pressure and collaboration dominate in others. Rather than treating these differences as contradictory, a readiness perspective interprets them as evidence that technology, processes, people, organizational arrangements, and external conditions perform different but complementary roles.

2.3 From Adoption Intention toward Implementation Readiness

Adoption intention and implementation readiness are related, but distinct constructs. Adoption intention is an attitudinal or decision-oriented outcome: whether an organization is willing to adopt an innovation. Implementation readiness is a capability-oriented outcome: whether the organization can operationalize and sustain that innovation through infrastructure, routines, governance, competent users, and ecosystem support. A firm may approve a blockchain initiative yet lack interoperable systems, standardized workflows, accountable ownership, or willing partners. Treating intention and readiness as equivalent, therefore, obscures why initiatives can stall after authorization and overstates what adoption models can explain.

2.4 Socio-Technical Capability Perspective

Socio-technical systems theory holds that organizational performance depends on the joint alignment of technical and social subsystems rather than on technology alone (Baxter & Sommerville, 2011). In this study, organizational, process, and human capabilities are separated because they refer to different levels of capability. Organizational capability concerns collective strategy, governance, culture, and committed resources; process maturity concerns routinized workflow integration, control, and execution; and people capability concerns knowledge, analytical competence, trust, and change readiness. The constructs may interact, but they are not interchangeable. Knowledge management and IT governance reinforce this distinction by showing how organizations create and apply expertise while aligning digital investments with operating responsibilities (Warner & Wäger, 2019; Kurniawan & Wella, 2023; Holman & Desanti, 2024).

2.5 Research Model Development and Hypothesis Development

Building on TOE and socio-technical systems theory, the model specifies five antecedent constructs. Technological capability encompasses secure, scalable infrastructure and integration capacity. Organizational capability reflects strategic alignment, governance, financial commitment, and an innovation-supportive culture. Environmental capability represents regulatory support, partner readiness, transparency, and ecosystem collaboration. Process maturity captures automation, workflow integration, operational governance, and risk control. People's capability reflects analytical competence, trust in digital systems, and change readiness. Blockchain implementation readiness is the higher-order organizational capacity to deploy, integrate, govern, and derive operational value from blockchain-enabled processes.

The model proposes direct effects from all five constructs on blockchain implementation readiness and a technology-process–readiness pathway. Environmental capability is expected to be especially relevant because blockchain value depends on shared governance, regulatory alignment, interoperability, and inter-organizational trust. The hypotheses are stated as follows:

H1: Technological capability positively influences blockchain implementation readiness.
H2: Organizational capability positively influences blockchain implementation readiness.
H3: Environmental capability positively influences blockchain implementation readiness.
H4: Process maturity positively influences blockchain implementation readiness.
H5: People's capability positively influences blockchain implementation readiness.

H6: Process maturity mediates the relationship between technological capability and blockchain implementation readiness.

Critically comparing the main research perspectives is shown in Table 1.

Table 1. Critical Comparison of Research Perspectives

Perspective	Primary question	Typical outcome	Limitation for implementation readiness	Role in this study
Adoption-oriented TOE	Will the organization adopt blockchain?	Intention or adoption decision	Does not establish post-decision capability to deploy and sustain the system.	Provides the technology, organization, and environment contexts.
Implementation-barrier research	What prevents blockchain deployment?	Lists of technical, regulatory, and organizational barriers	Often descriptive and does not specify capability relationships.	Motivates a capability-based outcome and explicit construct boundaries.
Socio-technical capability view	How are technical and social resources jointly organized?	Alignment among technology, structures, routines, people, and context	Rarely operationalized together in enterprise blockchain models.	Justifies separate process and human constructs and complementary interpretation.
Present study	Which capabilities relate to readiness, and is process maturity a pathway?	Direct effects, exploratory auxiliary paths, and an indirect-effect test	Exploratory sample and modest explanatory power limit causal and general claims.	Extends TOE while matching theoretical claims to the empirical evidence.

Specifications of the operational boundaries and retained indicators is shown in Table 2.

Table 2. Construct Operationalization and Retained Indicators

Construct	Theoretical boundary	Retained indicators	Source basis	Model role
Blockchain implementation readiness (BIE)	Integrated capacity to deploy, govern, sustain, and derive operational value from blockchain.	BIE1 support; BIE2 technology capability; BIE4 intelligence/HR preparedness; BIE5 operational and business value.	Sony & Naik (2020); Lustenberger et al. (2021)	Endogenous outcome
Technological capability (T)	Secure, scalable, interoperable, and adaptable technical infrastructure.	T2 security; T3 adaptive smart contracts; T4 infrastructure readiness; T5 scalability/performance.	Schumacher et al. (2016); Viriyasitavat et al. (2020);	Direct predictor; antecedent of process
Organizational capability (O)	Strategy, governance, culture, and committed financial resources.	O1 strategy; O3 innovation/change culture; O4 transparency/traceability governance; O6 finance.	Van Haaren et al. (2022)	Direct predictor
Environmental capability (E)	Regulatory, partner, transparency, and ecosystem conditions external to the focal organization.	E1 ecosystem; E2 supply-chain transparency; E3 regulatory/compliance; E6 government regulation.	Lustenberger et al. (2021); Queiroz & Wamba (2019); Orji et al, (2020).	Direct predictor
Process maturity (PR)	Routinized workflow integration, automation, operational control, and risk management.	PR1 logistics/operational efficiency; PR3 process automation; PR6 risk management.	Viriyasitavat et al. (2020)	Direct predictor; proposed mediator
People capability (P)	Analytical competence, trust, and readiness for organizational change.	P1 trust in digital systems; P2 analytical competence; P3 change readiness.	Vial (2019); Oliveira & Martins (2011); Warner & Wäger (2019).	Direct predictor

The literature supports the relevance of technological, organizational, environmental, process, and people factors, but it remains fragmented across adoption, operations, and digital transformation studies. The proposed model integrates these streams by treating implementation readiness as a socio-technical capability and by examining process maturity and people capability as distinct dimensions rather than as residual elements of organizational readiness. Literature Mapping of Model Constructs and Indicators is shown in Table 3.

Table 3. Literature Mapping of Model Constructs and Indicators

ID	References	Factor	Definition
E1	Wachnik (2022)	Competitive Pressure and Ecosystem Collaboration	Captures competitive pressure and collaboration across industries and supply chains.
E2	Narayanan et al. (2024)	Supply Chain Transparency	Reflects visibility and traceability as motives for enterprise blockchain integration.
E3	Ngo et al. (2023)	Regulatory Certainty and Compliance	Captures regulatory harmonization, data protection, and compliance across jurisdictions.
E4	Lustenberger et al. (2021)	Ecosystem Readiness	Indicates whether partner ecosystems possess the capabilities required for implementation.
E5	Casino et al. (2019); Liu et al. (2024)	Transparency	Captures the visibility and traceability of data shared through decentralized systems.
E6	Queiroz & Wamba (2019); Orji et al. (2020).	Government Regulation	Represents the legal and institutional frameworks governing adoption, compliance, and accountability.
O1	Singh et al. (2025)	Top-Management Support	Represents senior-management commitment and leadership support for blockchain implementation.
O2	Zhang et al. (2025); Van Haaren et al. (2022)	Standardization and Interoperability	Captures technical standards and interoperability across platforms.
O3	Cao et al. (2025);	Innovation and Change Culture	Reflects a culture that supports innovation and manages resistance to change.
O4	Lambert et al. (2023)	Supply-Chain Transparency and Traceability	Represents blockchain as a shared source of truth for supply-chain visibility.
O5	Anatan & Nur (2023)	Financial Readiness	Reflects the financial resources available for enterprise-system or digital-technology adoption.
O6	Kumar et al. (2025)	Organizational Finance	Captures financial capacity for blockchain investment, implementation, and continuity.
O7	Verhoef et al. (2021); Kraus et al. (2023)	Business Strategy	Represents alignment between blockchain initiatives and long-term business objectives.
P1	Al-Jaroodi & Mohamed (2019)	Blockchain Security and Immutability	Captures secure, integral, and immutable record keeping.
P2	Verhoef et al. (2021)	Analytical competence	Reflects users' analytical competence for enterprise-system automation.
P3	Vial (2019)	Change Readiness	Reflects individual readiness to participate in digital transformation.
P4	Frizzo et al. (2020)	Blockchain Confidence	Captures user confidence in blockchain-enabled operational data.
P5	Kraus et al. (2023)	Digital Literacy and AI	Reflects the ability to understand, use, and apply AI-enabled digital technologies.
P6	Singh et al. (2025)	Blockchain Competence and Expertise	Captures the expertise required to implement and use blockchain.

ID	References	Factor	Definition
P7	Oliveira & Martins (2011)	Trust in Digital Systems	Reflects trust in decentralized digital systems.
PR1	Viriyasitavat et al. (2020)	Enterprise-System Integration	Captures the integration of enterprise systems and blockchain for real-time operational decisions.
PR2	Sony & Naik (2020)	Perceived Operational Necessity	Reflects the perceived necessity of blockchain for integrated enterprise operations.
PR3	Viriyasitavat et al. (2020)	Business-Process Automation	Captures reductions in manual intervention through smart contracts.
PR4	Verhoef et al. (2021)	Marketing Processes	Reflects organizational use of social media, marketplaces, and digital advertising.
PR5	Van Haaren et al. (2022)	Internal Governance and Standardization	Captures integrated technical and legal governance.
PR6	Salah et al. (2019)	Risk Management and Anomaly Detection	Reflects AI-enabled anomaly detection and risk control in blockchain governance.
PR7	Shahzad et al. (2025)	Logistics and Operational Efficiency	Captures process automation, real-time monitoring, and predictive maintenance.
T1	Salah et al. (2019)	Blockchain Integration with AI and IoT	Reflects the integration of blockchain, AI, and IoT for enterprise intelligence.
T2	Viriyasitavat et al. (2020)	Legacy-System Interoperability and Integration	Captures integration with ERP, logistics systems, and digital platforms.
T3	Viriyasitavat et al. (2020)	Adaptive Smart Contracts	Reflects dynamic rule updates and anomaly detection through smart contracts.
T4	Schumacher et al. (2016)	Digital-Infrastructure Readiness	Captures infrastructure that supports AI, IoT, cloud computing, and digital twins.
T5	Schumacher et al. (2016)	System Scalability and Performance	Reflects transaction speed, processing capacity, and energy efficiency.
T6	Panarello et al. (2018);	Blockchain Integration	Captures seamless integration with existing enterprise systems.
T7	Al-Jaroodi & Mohamed (2019)	Blockchain-System Security	Reflects data integrity, confidentiality, and resilience against attacks.

3. Materials and Methods

This section describes research design, sampling, measurement development, and PLS-SEM procedures.

3.1 Research Design

A cross-sectional quantitative survey was used to examine blockchain implementation readiness from a socio-technical capability perspective. TOE provides the cross-context structure, while process maturity and people capability capture operational and social mechanisms that are not isolated in the conventional framework. PLS-SEM was selected because the study extends an existing theory, emphasizes prediction and explanation, and estimates multiple direct and indirect relationships (Hair & Alamer, 2022).

3.2 *Population*, Sampling, and Data Collection

The target population comprised professionals involved in enterprise digital transformation, enterprise systems, information systems management, blockchain initiatives, or related technology projects. Purposive sampling was used

because respondents were required to have relevant organizational and technical experience. The questionnaire was distributed electronically through professional networks and industry communities. After data screening, 101 valid responses were retained for analysis. The sample included 57.4% men and 42.6% women, with most respondents aged 21–40 years. Participants represented operational, middle-management, and senior-management roles across information technology, manufacturing, financial services, logistics, and other digital sectors. The diversity provides operational and strategic perspectives, but does not make the purposive sample representative of a national or industry population. Under the inverse-square-root approximation for PLS-SEM, N = 101 is sufficient to detect path coefficients of approximately 0.25 at the 5% level, but it is not well powered for small effects. Nonsignificant coefficients are therefore interpreted cautiously rather than as proof of no relationship.

3.3 Measurement Development

The model contains six reflective constructs adapted from prior studies and refined through expert review and pilot testing. Table 2 reports each construct's theoretical boundary, retained indicators, and source basis. This explicit separation is intended to reduce conceptual overlap among organizational capability, process maturity, and people capability.

Organizational capability encompasses business strategy, an innovation- and change-supportive culture, transparent and traceable governance, and financial capacity.Environmental capability encompasses competitive and collaborative ecosystem conditions, supply chain transparency, regulatory and compliance support, and government regulation. Process maturity measures logistics and operational efficiency, business-process automation, and risk management. People’s capability measures trust in digital systems, analytical competence, and change readiness.

Blockchain implementation readiness measures included integrated organizational and ecosystem support, blockchain capability, intelligence and human resource preparedness, and expected operational and business value.

All indicators were measured on a five-point Likert scale from 1 (strongly disagree) to 5 (strongly agree).

Before the main survey, domain experts reviewed the instrument, and a pilot test assessed wording, contextual relevance, and content validity. Minor revisions were made before data collection.

3.4 Data Analysis

The model was analyzed using SmartPLS 4 following the PLS-SEM assessment procedures described by Hair & Alamer (2022). The measurement model was assessed for indicator reliability, internal consistency, convergent validity, discriminant validity, and collinearity. Standardized loadings above 0.70 were treated as acceptable. Cronbach's alpha and composite reliability values above 0.70 indicated internal consistency, and average variance extracted (AVE) values above 0.50 indicated convergent validity. Discriminant validity was assessed with the heterotrait-monotrait ratio (HTMT) and cross-loadings. Collinearity was evaluated using variance inflation factors (VIFs).

The structural model was evaluated with 5,000 bootstrap resamples to estimate direct-path coefficients, t-values, and p-values. R^2 and f^2 assessed explanatory and practical relevance, while SRMR and NFI were treated as supplementary fit indices. The source file did not contain bootstrapped confidence intervals for the specific indirect effects; therefore, the mediation hypothesis was additionally evaluated with a transparent normal-theory Sobel approximation computed from the reported path coefficients and standard errors. This test is reported as a robustness check and not as a substitute for exporting the original SmartPLS bootstrap confidence interval.

The hypothesized paths are distinguished from three auxiliary paths retained in the original exploratory SmartPLS specification: technology to organization, organization to environment, and process to environment. These auxiliary associations are reported separately and are not used to infer causal ordering. In particular, the process–environment coefficient is treated as sample-specific and exploratory, not as evidence that internal processes determine the external environment.

3.5 Research Model

Figure 1 presents the hypothesized model. Each capability is specified as a direct antecedent of blockchain implementation readiness, and technological capability also predicts process maturity. Auxiliary cross-capability paths from the original exploratory specification are excluded from Figure 1 and are identified separately in the results.

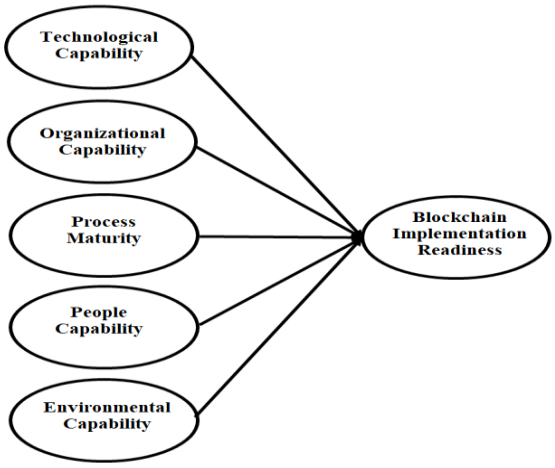


Figure 1. Proposed Research Model

Following indicator purification, the retained measurement items are summarized in Table 4.

Table 4. Purified Measurement Model

No	Construct	FL	CA	CR	AVE	Standardised factor loadings (p-values)						
						BIE	E	O	P	PR	T	p-values
1	BIE1-Organizational and Ecosystem Support	0.703	0.860	0.910	0.720	0.710						< 0.001
2	BIE2-Blockchain Technology Capabilities	0.836				0.840						< 0.001
3	BIE4-Intelligence & HR Capabilities	0.943				0.950						< 0.001
4	BIE5-Operational Impact and Business Value	0.891				0.900						< 0.001
5	E1-Competitive and Collaborative Ecosystem	0.831	0.880	0.920	0.740		0.840					< 0.001
6	E2-Supply Chain Transparency	0.927					0.930					< 0.001
7	E3-Regulatory & Compliance	0.847					0.850					< 0.001
8	E6-Government regulations	0.834					0.840					< 0.001
9	O1-Organizational business strategy	0.701	0.860	0.900	0.680			0.710				< 0.001
10	O3-Culture of Innovation & Change	0.893						0.900				< 0.001
11	O4-Supply Chain Transparency & Traceability	0.824						0.830				< 0.001
12	O6-organizational finances	0.876						0.880				< 0.001
13	P1-Trust in Digital Systems	0.739	0.710	0.830	0.620				0.740			< 0.001
14	P2-analytical competence	0.717							0.720			< 0.001

No	Construct	FL	CA	CR	AVE	Standardised factor loadings (p-values)						
						BIE	E	O	P	PR	T	p-values
15	P3-Change Readiness	0.898							0.900			< 0.001
16	PR1-Logistics and Operational Efficiency	0.953								0.960		< 0.001
17	PR3-Business Process Automation	0.775	0.880	0.920	0.800					0.780		< 0.001
18	PR6-Risk Management	0.953								0.960		< 0.001
19	T2-Blockchain system security	0.789									0.790	< 0.001
20	T3-Smart Contract Adaptif	0.871									0.880	< 0.001
21	T4-Digital Infrastructure Readiness	0.943	0.880	0.910	0.720						0.950	< 0.001
22	T5-System Scalability and Performance	0.783									0.790	< 0.001
						0.850	0.865	0.830	0.787	0.900	0.853	

4. Results

4.1 Measurement Model Assessment

All retained indicators loaded between 0.701 and 0.953, meeting the 0.70 criterion. Cronbach's alpha ranged from 0.71 to 0.88, composite reliability from 0.83 to 0.92, and AVE from 0.62 to 0.80. These results support indicator reliability, internal consistency, and convergent validity. The outer loadings are reported in Table 5. It shows that each retained indicator met the minimum loading requirement.

Table 5. Outer Loadings of Retained Indicators

Construct	Indicator	Outer Loading	Decision
Blockchain Implementation Readiness	BIE1	0.703	Accepted
	BIE2	0.835	Accepted
	BIE4	0.943	Accepted
	BIE5	0.890	Accepted
Environmental Capability	E1	0.830	Accepted
	E2	0.926	Accepted
	E3	0.847	Accepted
	E6	0.833	Accepted
Organizational Capability	O1	0.701	Accepted
	O3	0.893	Accepted
	O4	0.823	Accepted
	O6	0.876	Accepted
People Capability	P1	0.739	Accepted
	P2	0.716	Accepted
	P3	0.897	Accepted
Process Maturity	PR1	0.953	Accepted
	PR3	0.774	Accepted
	PR6	0.952	Accepted
Technological Capability	T2	0.789	Accepted
	T3	0.871	Accepted
	T4	0.943	Accepted
	T5	0.782	Accepted

Construct reliability was assessed using Cronbach's alpha and composite reliability, while convergent validity was assessed using AVE, as shown in Table 6.

Table 6. Construct Reliability and Convergent Validity

Construct	No of item	CA	CR	AVE	Latent Variable - Covariances					
					BIE	E	O	P	PR	T
BIE-Blockchain in Intelligent Enterprise	4	0.860	0.910	0.720	1.000	0.230	0.070	0.160	0.170	0.160
E-Environment	4	0.880	0.920	0.740	0.230	1.000	0.080	0.020	-0.190	-0.020
O-Organization	4	0.860	0.900	0.680	0.070	0.080	1.000	0.100	0.140	0.110
P-People	3	0.710	0.830	0.620	0.160	0.020	0.100	1.000	0.030	0.060
PR-Process	3	0.880	0.920	0.800	0.170	-0.190	0.140	0.030	1.000	0.240
T-Technology	4	0.880	0.910	0.720	0.160	-0.020	0.110	0.060	0.240	1.000

CA = Cronbach Alpha. CR= Composite Reliabilities. AVE= Average Variance Extract

As shown in Table 6, every construct exceeded the recommended thresholds for internal consistency and convergent validity.

4.2 Discriminant Validity

Discriminant validity was assessed with HTMT and cross-loadings. HTMT values ranged from 0.080 to 0.261, well below the 0.85 threshold. Each indicator also loaded more strongly on its assigned construct than on the alternatives. Together, these results indicate that the constructs are empirically distinct. Table 7 reports the HTMT matrix. Table 8 provides complementary cross-loading results.

Table 7. Heterotrait-Monotrait Ratio Matrix

	BIE	Environment	Organization	People	Process	Technology
BIE						
Environment	0.261					
Organization	0.126	0.080				
People	0.194	0.103	0.128			
Process	0.191	0.198	0.185	0.110		
Technology	0.160	0.128	0.164	0.125	0.226	

Table 8. Cross-Loading Analysis

	BIE	Environment	Organization	People	Process	Technology
BIE1	0.703					
BIE2	0.835					
BIE4	0.943					
BIE5	0.890					
E1		0.830				
E2		0.926				
E3		0.847				
E6		0.833				
O1			0.701			
O3			0.893			
O4			0.823			
O6			0.876			
P1				0.739		
P2				0.716		
P3				0.897		
PR1					0.953	
PR3					0.774	
PR6					0.952	
T2						0.789
T3						0.871
T4						0.943
T5						0.782

The cross-loadings in Table 8 confirm that every indicator loaded highest on its intended construct, providing additional evidence of discriminant validity.

4.3 Collinearity Assessment

Collinearity was assessed using VIFs. All values were below the prespecified threshold of 5.5, indicating no critical collinearity problem under that criterion. However, BIE4 (5.266) and T4 (4.959) were close to the limit and should be monitored when interpreting the estimates.

Table 9. Indicator Collinearity Statistics

Collinearity statistics (VIF)	VIF
BIE1	1.446
BIE2	2.445
BIE4	5.266
BIE5	3.518
E1	2.661
E2	4.429
E3	2.420
E6	1.800
O1	2.395
O3	4.288
O4	1.588
O6	2.875
P1	1.182
P2	1.851
P3	1.990
PR1	4.065
PR3	1.779
PR6	4.309
T2	2.585
T3	3.398
T4	2.881
T5	1.845

4.4 Structural Model Assessment

Structural paths were estimated with 5,000 bootstrap resamples. Table 10 reports the coefficients, t-values, p-values, and significance decisions.

Table 10. Structural Model Bootstrapping Results

Structural path	Model status	β	t	p	Decision
Environment → BIE	H3	0.262	2.834	0.005	Supported
Organization → BIE	H2	-0.004	0.037	0.971	Not supported
Human → BIE	H5	0.139	1.057	0.291	Not supported
Process → BIE	H4	0.191	1.744	0.081	Not supported
Technology → BIE	H1	0.111	1.076	0.282	Not supported
Technology → Process	H6 antecedent path	0.241	2.147	0.032	Significant
Technology → Organization	Exploratory	0.113	1.136	0.256	Nonsignificant
Organization → Environment	Exploratory	0.111	0.758	0.448	Nonsignificant
Process → Environment	Exploratory	-0.208	2.130	0.033	Significant; post hoc

Among the direct predictors of blockchain implementation readiness, only environmental capability was significant (β = 0.262, t = 2.834, p = 0.005), supporting H3. The direct effects of technological capability (β = 0.111, p = 0.282), organizational capability (β = -0.004, p = 0.971), process maturity (β = 0.191, p = 0.081), and people capability (β = 0.139, p = 0.291) were not significant; thus, H1, H2, H4, and H5 were not supported. Technological capability significantly predicted process maturity (β = 0.241, p = 0.032). Two additional paths were estimated: process maturity negatively predicted environmental capability (β = -0.208, p = 0.033), whereas the organizational-environmental and technology-organizational paths were not significant.

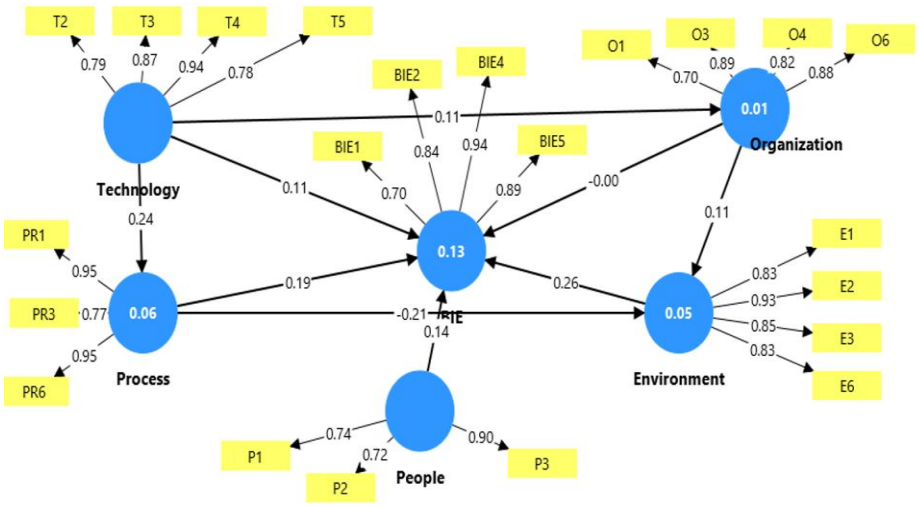


Figure 2. Estimated PLS-SEM Model

Figure 2 summarizes the estimated PLS-SEM model after indicator purification. The figure confirms the dominant direct role of environmental capability and the significant technology-to-process path. The remaining direct paths to readiness are positive, but nonsignificant, except for the near-zero organizational effect.

4.5 Mediation Analysis

Specific indirect coefficients were inspected to evaluate the proposed capability-building mechanisms. Because Table 11 reports coefficients without bootstrap t-values, p-values, or confidence intervals, these estimates are interpreted descriptively rather than as confirmed mediation effects.

Table 11. Specific Indirect-Effect Coefficients

Specific Indirect Path	β
Technology → Process → BIE	0.046
Organization → Environment → BIE	0.029
Technology → Process → Environment	-0.050
Process → Environment → BIE	-0.054

The technology-process-readiness path produced a small positive indirect coefficient (β = 0.046). The organization-environment-readiness path was also positive, but small (β = 0.029), whereas the technology-process-environment (β = -0.050) and process-environment-readiness (β = -0.054) paths were negative. These patterns are consistent with multiple indirect pathways, but H6 cannot be confirmed without inferential statistics for the specific indirect effect.

4.6 Explanatory Power

The model explained 13.1% of the variance in blockchain implementation readiness, 5.8% in process maturity, 4.9% in environmental capability, and 1.3% in organizational capability (Table 12).

Table 12. Coefficient of Determination

Construct	R=square
BIE	0.13
Environment	0.05
Organization	0.01
Process	0.06

The R^2 values indicate modest explanatory coverage. They are consistent with an exploratory model, but also show that important determinants of implementation readiness remain outside the current specification.

4.7 Effect Size

Cohen's f^2 was used to assess the practical contribution of each predictor (Table 13).

Table 13. Effect Sizes

Relationship	f^2	Interpretation
Environment → BIE	0.075	Small
Organization → BIE	0.000	Negligible
People → BIE	0.022	Small
Process → BIE	0.037	Small
Technology → BIE	0.013	Small
Technology → Process	0.062	Small

Effect sizes ranged from negligible to small. Environmental capability had the largest effect on readiness ($f^2 = 0.075$), followed by process maturity (0.037), people capability (0.022), and technological capability (0.013). Organizational capability had a negligible effect (0.000). The technology-to-process relationship also had a small effect (0.062). These results reinforce the importance of the ecosystem while showing that no individual internal capability had a large practical effect.

4.8 Model Fit

Model fit was summarized using SRMR and NFI.

Table 14. Model-Fit Indices

Indicator	Result	Threhold	Interpretation
SRMR	0.078	<0.08	Good
NFI	0.713	exploratory	Acceptable

The SRMR was 0.078, marginally below the 0.08 benchmark and therefore consistent with an acceptable residual fit. The NFI was 0.713, below the conventional 0.90 benchmark. Because NFI is supplementary in PLS-SEM, it should not be treated as a stand-alone rejection criterion; nevertheless, the low value warrants caution and precludes a strong claim of overall fit.

The results identify environmental capability as the principal direct predictor of readiness and provide partial evidence that technological capability contributes through process development.

5. Discussion

5.1 Blockchain Implementation Readiness as a Socio-Technical Capability

The findings support a socio-technical interpretation of blockchain implementation readiness. Blockchain operates across decentralized networks in which value depends on shared governance, trusted data, compatible processes, and coordinated participation. Readiness therefore, cannot be reduced to the possession of technical infrastructure; it reflects the alignment of internal capabilities with external ecosystem conditions. This interpretation extends adoption-oriented research by focusing on the capabilities required to operationalize blockchain after an adoption decision. The significant environmental effect is consistent with studies that emphasize ecosystem collaboration, regulation, and inter-organizational coordination (Casino et al., 2019; Treiblmaier, 2018). At the same time, the nonsignificant internal paths show that technology, organization, processes, and people do not independently guarantee readiness.

The model's low explanatory power indicates that readiness is influenced by additional conditions not captured here. The results should therefore be read as an exploratory capability pattern rather than as a complete causal account of enterprise blockchain implementation. Figure 3 presents a refined conceptual interpretation of the empirical results.

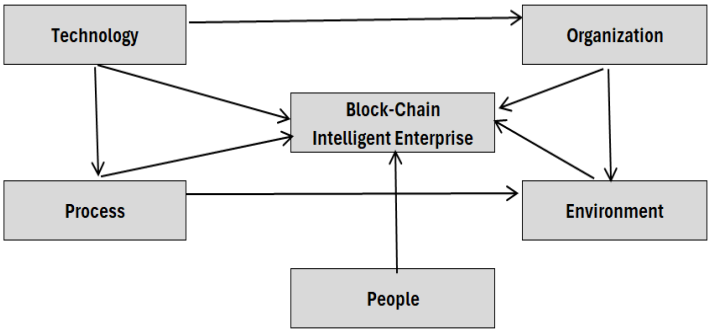


Figure 3. Refined Blockchain Intelligent Enterprise Model

The refined model positions blockchain implementation readiness at the intersection of technological, organizational, process, human, and environmental capabilities. It emphasizes alignment between internal transformation and the external ecosystem rather than a technology-first sequence. Technological capability enables process development, while environmental capability provides the regulatory, collaborative, and trust conditions that directly support readiness. Organizational and human capabilities remain important as complementary resources, but their effects may operate through process improvement, learning, governance, or ecosystem engagement rather than through direct paths.

The findings answer RQ1 by identifying environmental capability as the only significant direct predictor of readiness. For RQ2, separating process maturity and people capability clarifies their distinct roles, but the available indirect-effect statistics do not conclusively establish mediation. For RQ3, the extended model shows that blockchain readiness is best understood as an ecosystem-dependent capability configuration, although the modest R^2 limits claims of comprehensiveness.

5.2 The Dominant Role of Environmental Capability

The significant environmental effect reflects the inter-organizational nature of blockchain. Implementation depends on regulatory clarity, institutional trust, partner readiness, shared standards, and supply-chain coordination. These conditions reduce uncertainty and make it easier to exchange data and govern transactions across organizational boundaries. This result is consistent with TOE-based studies that identify environmental conditions as important drivers of blockchain adoption and implementation (Orji et al., 2020). The present study adds that these conditions matter not only for deciding to adopt blockchain, but also for developing the capability to implement it. In this sample, ecosystem maturity was more consequential than internal willingness or resource commitment alone.

5.3 The Role of Technological Capability in Process Transformation

Technological capability significantly strengthened process maturity, indicating that infrastructure and integration capacity can support operational development. However, process maturity did not directly predict readiness at the 5% level ($p = 0.081$), and the reported indirect coefficient was small. The evidence therefore, suggests, but does not confirm, that process transformation is the mechanism through which technology contributes to readiness. This qualified interpretation remains consistent with socio-technical theory: technology creates organizational value when it is embedded in redesigned workflows, governance, and operating routines. Future analyses should report bootstrapped confidence intervals for the indirect effect and test whether the pathway varies by industry, implementation stage, or ecosystem maturity.

5.4 Interpreting the Non-Significant Organizational and Human Effects

The nonsignificant organizational and human effects should not be interpreted as evidence that leadership, governance, competence, or change readiness are unimportant. Rather, their influence may be indirect, contingent, or already reflected in process and environmental conditions. For example, leadership and employee capability may improve readiness by enabling process redesign, organizational learning, and partner coordination. This interpretation accords with socio-technical systems theory, which emphasizes complementarity among capabilities. It may also explain why prior blockchain studies report inconsistent organizational effects: internal resources may matter only when they are combined with mature processes and a supportive external ecosystem.

5.5 Explaining the Modest Explanatory Power

The model explains only a limited share of the variance in readiness. This result is compatible with an exploratory design, but it also constrains the strength of the conclusions. Potentially important, omitted factors include digital maturity, governance quality, cybersecurity readiness, project experience, organizational learning, implementation stage, strategic partnerships, and institutional pressure. Future research should test these determinants, compare alternative model specifications, and examine whether combinations of capabilities are more informative than

independent net effects. Longitudinal and configurational designs would be particularly useful for capturing how readiness develops over time and across contexts.

6. Implications and Contributions

6.1 Theoretical Contributions

The study makes three theoretical contributions. First, it separates implementation readiness from adoption intention and defines readiness as the capability to deploy, integrate, govern, and sustain blockchain. Second, it extends TOE by modeling process maturity and people capability as distinct socio-technical dimensions. Third, it shows that environmental capability has greater direct explanatory relevance than internal capabilities in this sample, while technological capability is more closely associated with process development than with readiness itself. These contributions provide a more differentiated, although still exploratory, account of enterprise blockchain implementation.

6.2 Practical Implications

Managers should assess blockchain readiness as a portfolio of interdependent capabilities rather than as a technology-purchasing decision. The first priority is to evaluate ecosystem conditions, including regulatory clarity, partner commitment, data-sharing rules, interoperability standards, and joint governance. Internally, organizations should connect technical investments to process redesign, risk controls, and clearly assigned ownership. Workforce development remains necessary, but training should be tied to specific workflows and implementation responsibilities. A staged readiness assessment that combines ecosystem, process, governance, technology, and human indicators can help organizations identify bottlenecks before scaling blockchain initiatives.

7. Conclusion

This study developed and tested an extended TOE model of blockchain implementation readiness using a socio-technical capability perspective. Environmental capability was the only significant direct predictor of readiness, whereas technological capability was a significant predictor of process maturity. The direct effects of technological, organizational, process, and human capabilities on readiness were not significant. These results shift attention from blockchain acquisition to the ecosystem and operational conditions required for implementation. They also suggest a technology-to-process pathway, although the mediation claim requires additional inferential evidence. Because the model explains only a modest share of the variance in readiness, its contribution is primarily conceptual and exploratory. Organizations should therefore strengthen external alignment and process transformation while treating governance and people capability as complementary enablers.

8. Limitations and Future Research

Several limitations qualify the findings. The cross-sectional design does not establish causality or show how readiness changes over time. The purposive sample of 101 respondents supports exploratory PLS-SEM analysis, but limits statistical power and generalizability across industries and countries. The model explains only 13.1% of the variance in readiness, indicating substantial omitted determinants. Future studies should incorporate digital maturity, organizational learning, cybersecurity readiness, governance quality, implementation experience, institutional pressure, and strategic partnerships. They should also report complete bootstrap statistics for indirect effects, validate the measurement coding and construct labels, and use longitudinal, multi-group, or configurational methods such as fsQCA to examine asymmetric capability combinations. Replication across organizational settings would further strengthen external validity and practical relevance.

Author Contributions

Santo Fernandi Wijaya: Conceptualization, Methodology, Formal Analysis, Investigation, Validation, Writing – Original Draft, Visualization.

Jansen Wiratama: Conceptualization, Methodology, Supervision, Validation, Writing – Review & Editing.

Data Availability **Statement**

The data supporting the findings of this study are available from the corresponding author upon reasonable request, subject to applicable confidentiality and research ethics considerations

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Ethical Considerations

Participation was voluntary, with respondents informed of the study purpose. All responses were anonymous and used solely for research.

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Conflict of Interest

The authors declare no conflict of interest.

Declaration of Generative AI and AI-assisted technologies in the writing process

During the preparation of this manuscript, ChatGPT was used solely for language editing, grammar correction, and improving readability. The tool was not used for data collection, data analysis, methodology development, drafting results, interpreting findings, or drawing conclusions. The authors reviewed, edited, and approved all AI-assisted language revisions and bear full responsibility for the content of this manuscript.

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