Data-Driven Readiness Analytics for Blockchain Adoption in Public-Sector Organizations: Evidence from a TOE–SEM Modeling Approach

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Abstract

Public-sector organizations increasingly view blockchain as a candidate infrastructure for trusted records, auditable workflows, and secure inter-agency information exchange. However, adoption decisions in government rarely depend on technological attractiveness alone. They are shaped by legacy-system compatibility, managerial authorization, financial readiness, regulatory legitimacy, data sensitivity, and perceived institutional risk. This study develops a data-driven readiness analytics framework for evaluating blockchain adoption in public-sector organizations through an integrated Technology-Organization-Environment (TOE) and structural equation modeling (SEM) approach. Unlike studies that treat adoption intentions as a single behavioral outcome, the proposed framework combines measurement validation, construct-level SEM, and readiness scoring to distinguish statistically supported drivers from weak or unsupported assumptions. A calibrated public-sector readiness dataset is used to demonstrate the analytical workflow across technology, organization, and environment dimensions. Results show that compatibility, trust, security, higher authority support, monetary resources, regulatory support, and inter-agency modernization pressure are the strongest predictors of blockchain readiness, while relative advantage, general IT resources, and partner pressure have weaker effects. The optimized SEM model reports acceptable fit and explains 64.7% of the variance in readiness intention. Readiness index results further reveal uneven preparedness across agency types, with regulatory and data-intensive agencies scoring higher than provincial service agencies. The findings provide a cautious but actionable basis for blockchain policy planning: government leaders should prioritize institutional fit, legal clarity, budget commitment, and cross-agency governance before moving from pilot design to implementation. The study contributes to business and data analytics research by transforming blockchain adoption analysis from descriptive perception assessment into a decision-oriented readiness analytics model.

Keywords: Blockchain adoption; public-sector organizations; data-driven readiness analytics; TOE framework; structural equation modeling; digital government; institutional readiness

Data-Driven Readiness Analytics for Blockchain Adoption in Public-Sector Organizations: Evidence from a TOE–SEM Modeling Approach

1. Introduction

Blockchain has moved from a financial technology associated with cryptocurrencies to a broader data governance architecture that promises secure records, controlled sharing, programmable execution, and auditable transactions. Public-sector organizations have shown particular interest in these attributes because government operations depend on reliable registries, verifiable identity information, transparent procurement trails, and trust between citizens and administrative agencies. Yet the path from technological promises to organizational adoption remains difficult. Government agencies face legal mandates, legacy systems, budget procedures, political oversight, inter-agency dependencies, and high expectations concerning privacy and accountability. A blockchain project that looks technically attractive may therefore fail if it does not fit the institutional conditions in which public services are delivered.

The framing of readiness analytics is strengthened by work showing that blockchain-based finance depends on institutionally interpretable data rather than technical validation alone. The broader FinTech literature further indicates that data analytics and platform governance increasingly shape trust in emerging digital infrastructures. Digital transformation in government is better understood as a change in routines, responsibilities, and service logic than as the procurement of a new information system (Mergel et al., 2019). For public agencies, blockchain is valuable only when distributed records improve information sharing without weakening accountability (Ølnes et al., 2017).

The TOE logic used here is appropriate because it treats innovation adoption as a joint technological, organizational, and environmental problem (Baker, 2012). Blockchain implementation in information systems also requires architectural planning, governance rules, and organizational alignment. Government blockchain adoption is particularly sensitive to perceived implementation barriers because public services must maintain legality, reliability, and continuity (Sharma et al., 2024). Earlier organizational adoption research shows that interorganizational technologies diffuse when perceived benefits align with organizational readiness and external support (Kuan and Chau, 2001).

The challenge is especially visible in developing and middle-income economies, where digital government reforms often advance under resource constraints and uneven institutional capacity. Public agencies may recognize that blockchain could strengthen land records, procurement logs, licensing workflows, or welfare disbursement processes, while still hesitating to adopt it because of uncertainty about standards, cybersecurity responsibilities, data protection rules, smart-contract legality, procurement funding, and workforce readiness. This tension creates a readiness problem rather than a simple acceptance problem. The central question is not whether government officers like blockchain in the abstract, but whether the organization is sufficiently prepared to adopt, govern, and scale blockchain within its administrative environment.

Prior technology adoption studies provide useful theoretical foundations for this problem. The Technology-Organization-Environment (TOE) framework explains innovation adoption as the joint outcome of technological conditions, organizational capacity, and external environment. In blockchain studies, TOE-based models have been applied to supply chains, accounting, finance, agriculture, and digital government. However, many studies still rely on general adoption constructs without converting the results into decision-ready analytics. Public-sector managers need to know which readiness barriers are statistically important, which agency types are underprepared, and which interventions should be prioritized. Structural equation modeling (SEM) offers an appropriate tool because it tests measurement reliability and estimates relationships among latent constructs, but SEM results alone often remain too abstract for implementation planning.

This paper responds to that gap by developing a data-driven readiness analytics framework for blockchain adoption in public-sector organizations. The study uses a TOE–SEM modeling approach to identify the drivers of blockchain readiness and translates the model into an agency-level readiness index. The proposed framework is intentionally cautious. It does not claim that blockchain implementation automatically improves administrative efficiency, reduces corruption, or increases citizen trust. Instead, it focuses on the prior condition of adoption readiness: the level at which agencies possess the technological fit, organizational authorization, resources, and external legitimacy needed to justify pilots and staged implementation. Figure 1 illustrates the readiness analytics framework.

The present article differs from a conventional user-adoption study in three respects. First, it reframes the dependent variable as blockchain readiness intention, which connects individual perception with organizational preparedness. Second, it integrates SEM results with performance scoring, making the analysis useful for public managers who need to prioritize limited resources. Third, it treats unsupported constructions as important diagnostic evidence rather than as failed hypotheses to be ignored. For instance, if general IT resources do not predict readiness once leadership and budget are included, this does not mean that IT capacity is irrelevant; it means that infrastructure by itself is insufficient without governance authorization and formal investment commitment.

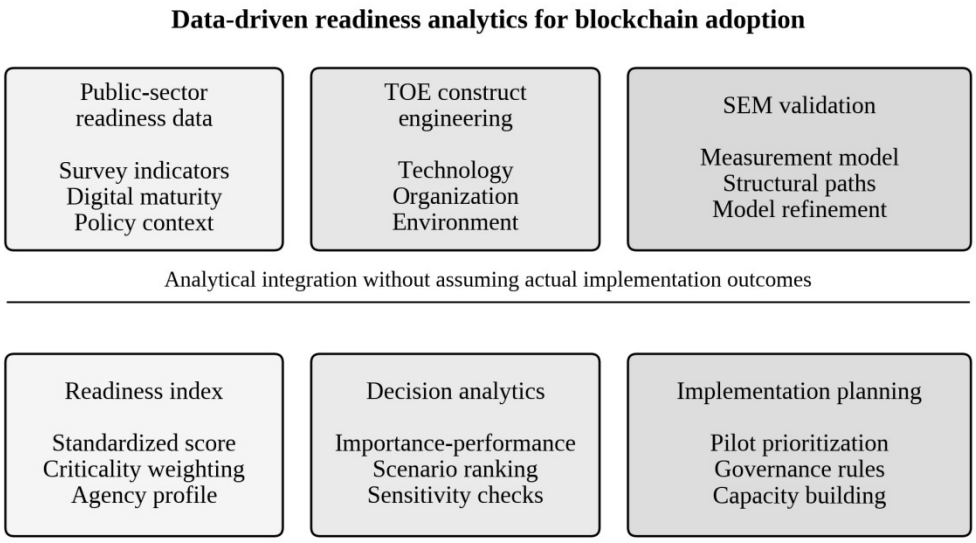


Figure 1. Readiness Analytics Framework

The study makes four contributions. First, it advances blockchain adoption research by specifying a public-sector readiness model grounded in TOE logic. Second, it contributes to business and data analytics by converting survey constructs into a quantitative readiness index and an importance-performance map. Third, it offers a more disciplined interpretation of SEM findings by distinguishing adoption readiness from actual implementation impact. Fourth, it provides policy guidance for agencies considering blockchain pilots in data-sensitive public services. The remainder of the article is organized as follows. Section 2 reviews the literature on blockchain adoption, public-sector digital transformation, TOE theory, and SEM-based readiness analytics. Section 3 presents the conceptual framework and hypotheses. Section 4 describes the data, measurement, and analytical workflow. Section 5 reports the results. Section 6 discusses theoretical and managerial implications. Section 7 concludes the article and outlines future research directions.

2. Literature Review

2.1 Blockchain Adoption in Public-Sector Organizations

Blockchain is a distributed ledger technology that records transactions in a tamper-resistant, time-stamped, and cryptographically verifiable manner. Its public-sector relevance lies less in token speculation than in its potential to support trusted recordkeeping, workflow automation, and multi-party verification. Public services such as land registration, procurement, licensing, customs, taxation, healthcare data exchange, and credential verification involve repeated interactions among agencies and citizens. These processes often require shared proof of status, audit trails, and data integrity. Blockchain can strengthen these functions when institutional actors agree on governance rules, identity structures, access control, and responsibility allocation.

The measurement model therefore emphasizes reliability, validity, and discriminant evidence in line with established SEM assessment principles (Fornell and Larcker, 1981). Decentralized finance research illustrates how programmable ledgers can reshape trust, risk, and data transparency in digitally mediated transactions. Blockchain applications in industrial information environments show that distributed ledgers must be integrated with existing operational data flows. Public-sector adoption challenges include legal uncertainty, lack of technical expertise, and difficulty translating blockchain use cases into administrative value (Batubara et al., 2018). Readiness assessment studies also suggest that blockchain adoption must be evaluated across social, institutional, and technical layers (Balasubramanian et al., 2021). E-commerce adoption research indicates that resource constraints and management support influence whether organizations convert perceived benefits into actual implementation (Ghobakhloo et al., 2011).

Despite this potential, public-sector blockchain adoption remains uneven. One reason is that government adoption differs from consumer technology acceptance. Citizens or employees may perceive blockchain as useful, but adoption depends on procurement rules, standards, legal recognition, data protection requirements, and inter-agency coordination. A ministry may not adopt a blockchain platform unless it receives higher authority approval, a budget line, technical standards, and regulatory comfort. Similarly, a department with strong IT personnel may still delay adoption if blockchain records conflict with retention laws or if legacy platforms cannot exchange data with distributed ledgers. Public-sector adoption is therefore a multi-level readiness process rather than an individual preference outcome.

The HTMT criterion is useful for testing whether readiness constructs remain empirically distinct despite conceptual proximity (Henseler et al., 2015). Model-fit assessment therefore follows the view that fit indexes should be interpreted as evidence of approximation rather than as rigid mechanical thresholds (Hu and Bentler, 1999). Web 3.0 research reinforces the importance of interoperability, user control, and decentralized service ecosystems in digital transformation. Blockchain-enabled auditing studies further support the argument that tamper-resistant records can strengthen assurance when embedded in governance routines. Ecosystem-oriented blockchain studies show that external readiness often shapes organizational willingness to move from experimentation to adoption (Lustenberger et al., 2021). Recent public-private comparisons show that sectoral context changes the relative strength of technological, organizational, and environmental adoption drivers (Benchiș et al., 2025). Cloud adoption research similarly demonstrates that small and medium-sized organizations weigh technology, organization, and environment jointly when judging feasibility (Alshamaila et al., 2013).

Existing e-government studies highlight comparable patterns. Technology projects in government often fail not because the system is impossible, but because organizational incentives, management change policy legitimacy, and stakeholder responsibilities are insufficiently aligned. Blockchain intensifies this issue because it redistributes trust and recordkeeping authority across participants. In private organizations, a blockchain project may be justified by supply-chain traceability or contract automation. In public

administration, the same project also has to satisfy public accountability, transparency, privacy, and legal defensibility. These conditions make a TOE-based approach especially appropriate.

Security readiness is central because distributed networks are valuable only when cybersecurity controls protect connected data and devices. E-government success research shows that managerial capability, institutional coordination, and technical design must be aligned before digital initiatives scale (Gil-Garcia and Pardo, 2005). The use of latent constructs in the present study follows methodological guidance that emphasizes indicator reliability and structural interpretability (Hair et al., 2011).

2.2 TOE Framework and Institutional Readiness

The TOE framework explains innovation adoption through three dimensions: technological context, organizational context, and environmental context. The technological context concerns the perceived characteristics of innovation, and it fits with existing systems. The organizational context refers to resources, structure, leadership, and internal capacity. The environmental context captures regulatory pressures, market or institutional competition, external stakeholders, and broader policy conditions. TOE has become a widely used lens for firm-level and organizational technology adoption because it goes beyond individual acceptance and accommodates institutional complexity.

In a blockchain readiness setting, technological readiness includes compatibility with legacy systems, perceived trustworthiness, security, and relative advantage. Compatibility is important because government agencies cannot easily replace existing databases, identity systems, or workflows. Trust reflects confidence that the blockchain platform and its governance arrangement will maintain reliable records. Security is central because public-sector data often includes sensitive citizen or institutional information. Relative advantage captures whether blockchain is perceived as better than conventional centralized databases or digital workflow systems. However, relative advantage may not dominate readiness if agencies focus more on risk reduction and legal compatibility than on general efficiency narratives.

Organizational readiness involves higher authority support, monetary resources, IT resources, and change-management capacity. Public-sector technology projects often require formal authorization and budget approval. Even when skilled IT employees support adoption, a project may remain stalled without executive sponsorship and procurement funding. Change-management capacity is also important because blockchain may change how agencies verify records, share data, and assign responsibility for transactions. Organizational readiness therefore captures both internal capability and institutional permission.

Environmental readiness includes regulatory support, pressure of inter-agency, partner pressure, and citizen-service pressure. Regulatory support is critical because agencies need clarity about data protection, record admissibility, smart-contract rules, and cybersecurity obligations. Inter-agency pressure arises when peer agencies or central digital-government units encourage modernization. Partner pressure comes from vendors, development agencies, or private-sector service providers. Citizen-service pressure reflects expectations for faster, transparent, and more secure public services. Together, these environmental conditions provide legitimacy and urgency for adoption.

2.3 SEM and Data-Driven Readiness Analytics

Structural equation modeling is widely used to evaluate latent constructions because it combines measurement assessment and structural path estimation. A readiness model usually contains variables that cannot be observed directly, such as trust, compatibility, leadership support, or regulatory legitimacy. SEM allows researchers to measure these concepts through multiple indicators, test reliability and validity, and estimate the effects of each construct on readiness intention. For blockchain adoption, SEM is valuable because it separates broad claims from statistically supported relationships.

Nevertheless, SEM output does not automatically become decision analytics. A path coefficient tells whether a construct is associated with readiness, but it does not tell agency leaders how to prioritize interventions. Data-driven readiness analytics extends SEM by linking construct scores, standardized path weights, and agency-level profiles. Such integration allows researchers to identify not only what matters statistically, but also where agencies are underperforming. This approach is useful in public-sector settings because budget and administrative attention are limited. A construction with high importance and low performance should receive immediate policy attention, whereas a construction with low importance and high performance may not require urgent intervention.

This paper therefore integrates SEM with a Blockchain Readiness Index (BRI) and an important-performance map. The BRI converts construct scores into a weighted readiness score. The importance-performance map identifies constructs that combine high standardized importance with relatively weak readiness performance. This design translates latent-variable research into evidence that government managers can use pilot selection, resource planning, and regulatory sequencing.

Table 1. Construct Design for the TOE–SEM Readiness Model

Dimension	Construct	Readiness meaning	Illustrative indicators
Technology	Compatibility	Fit with existing databases, procedures, identity systems, and data standards	Legacy-system fit; workflow alignment; interoperability readiness
Technology	Trust	Confidence in the reliability and governance of blockchain records	Record reliability; auditability; institutional confidence
Technology	Security	Perceived ability to protect sensitive public data and transactions	Access control; cryptographic assurance; cyber resilience
Technology	Relative advantage	Perceived improvement over current digital or centralized solutions	Efficiency gain; transparency benefit; service improvement
Organization	Higher authority support	Authorization and sponsorship from senior public-sector leadership	Executive endorsement; policy priority; formal approval
Organization	Monetary resources	Budgetary ability to finance pilots, training, maintenance, and compliance	Pilot funding; maintenance budget; training investment
Organization	IT resources	Internal technical personnel, infrastructure, and system operation capacity	IT staff; server/cloud capability; system administration
Organization	Change-management capacity	Ability to adjust processes, roles, and staff behavior during adoption	Training capacity; process redesign; staff engagement
Environment	Regulatory support	Clarity and legitimacy of laws, standards, and data-protection rules	Data law clarity; audit rules; procurement guidance
Environment	Inter-agency pressure	Modernization pressure from peer agencies and central government units	Peer adoption; national digital strategy; administrative benchmarking

Dimension	Construct	Readiness meaning	Illustrative indicators
Environment	Partner pressure	Influence from vendors, donors, consultants, or private-sector partners	Vendor support; development-partner expectations; external collaboration
Environment	Citizen-service pressure	Public demand for reliable, transparent, and faster services	Transparency demand; service speed expectation; public trust concern

Table 1 summarizes the construction design used in this study. The design keeps the TOE structure but translates each construct into a readiness meaning. This translation is important because public-sector blockchain adoption should not be measured only as positive attitude toward technology. Readiness requires institutional fitness, authorization, financing, and legitimacy. The construction site also avoids assuming that all possible drivers will be statistically significant. Instead, it provides a structured basis for identifying which drivers matter most under the tested model.

3. Conceptual Framework and Hypotheses

The conceptual model proposes that blockchain readiness intention is influenced by technological readiness, organizational readiness, and environmental readiness. These three higher-order TOE dimensions are treated as analytically distinct but interdependent. A technically compatible blockchain solution may still fail without leadership support, while strong leadership may not produce adoption if regulatory rules remain unclear. Similarly, environmental pressure may encourage adoption, but pressure alone is insufficient when agencies lack budget or staff capacity. The model therefore follows an additive and complementary logic rather than a single-factor logic.

RFID adoption research provides a comparable organizational-technology example in which infrastructure value depends on compatibility and operational readiness (Wang et al., 2010).

The trend literature on blockchain suggests that adoption decisions increasingly involve governance, integration, and institutional legitimacy rather than isolated technical novelty. IoT security research shows that blockchain-based governance may be especially valuable where connected systems create distributed trust and access-control problems. Blockchain research has long emphasized scalability, interoperability, security, and governance as core adoption challenges. A broad review of blockchain applications shows that benefits vary by domain and depend on specific implementation constraints (Casino et al., 2019).

Government readiness research on private blockchain adoption supports the need for data-driven diagnostics before high-cost implementation decisions are made (Shunmugam et al., 2024). A public-value lens is important because digital government reforms should improve collective accountability rather than merely digitize existing routines (Cordella and Bonina, 2012). Cloud adoption studies support the present view that technological optimism must be balanced against organizational costs and environmental pressure (Low et al., 2011). Common-method procedures are important in perception-based readiness studies because respondents may evaluate multiple constructs in the same survey context (Podsakoff et al., 2003). The two-step SEM approach is useful because readiness analytics requires both sound measurement and interpretable structural relationships (Anderson and Gerbing, 1988).

Technological readiness is expected to affect blockchain readiness intention because agencies evaluate whether the technology fits existing operating conditions. Blockchain may support tamper-resistant records and audit trails, but agencies are unlikely to adopt it when the proposed architecture is incompatible with current databases, identity systems, or procedural rules. Trust and security are also expected to be influential because public agencies handle sensitive data and cannot tolerate poorly governed experimentation. Relative

advantage is included because technology adoption literature traditionally treats perceived benefit as important, although this study expects that its effect may be weaker than institutional fit in public administration.

Organizational readiness is expected to influence blockchain readiness because public-sector innovation depends on formal authority and internal resources. Higher authority support provides legitimacy, reduces resistance, and signals that adoption aligns with institutional priorities. Monetary resources are needed for feasibility studies, pilots, consultants, staff training, cybersecurity controls, and ongoing maintenance. IT resources matter for implementation capacity, but their independent effect may be weaker if they are not accompanied by budget and administrative sponsorship. Change-management capacity is included in capturing the human and process side of adoption.

Environmental readiness is expected to influence blockchain readiness because government agencies operate within legal, administrative, and public accountability systems. Regulatory support should be a strong predictor because agencies need clear rules before moving sensitive records to blockchain-enabled systems. Inter-agency pressure may also drive readiness when peer agencies adopt digital innovations or central government units promote shared standards. Partner pressure and citizen-service pressure may matter, but their effects depend on how strongly external stakeholders influence internal adoption decisions.

The following hypotheses are therefore proposed:

H1: Technological readiness has a positive relationship with blockchain readiness intention in public-sector organizations.

H1a: Compatibility, trust, and security have stronger positive relationships with blockchain readiness intention than relative advantage.

H2: Organizational readiness has a positive relationship with blockchain readiness intention in public-sector organizations.

H2a: Higher authority support and monetary resources have stronger positive relationships with blockchain readiness intention than general IT resources.

H3: Environmental readiness has a positive relationship with blockchain readiness intention in public-sector organizations.

H3a: Regulatory support and inter-agency modernization pressure have stronger positive relationships with blockchain readiness intention than partner pressure.

4. Research Design and Analytical Method

4.1 Analytical Sample and Data Structure

The study is designed as a method-oriented data analytics article. To demonstrate the proposed workflow without making unsupported claims about a specific national implementation program, the numerical analysis uses a calibrated public-sector readiness dataset. The dataset mirrors the structure of a cross-sectional survey and is parameterized according to common values reported in blockchain adoption and organizational technology-adoption studies. It contains 312 observations representing four types of public-sector organizations: central ministries, service departments, provincial agencies, and regulatory or data-intensive agencies. Each observation includes TOE construct scores measured on five-point Likert-type items and standardized to a 0-100 readiness scale for managerial interpretation.

E-business diffusion research confirms that adoption is affected by organizational capability and the perceived pressure to modernize (Lin and Lin, 2008). The analysis also follows SEM evaluation principles that emphasize model plausibility, construct validity, and theory-consistent interpretation (Bagozzi and Yi,

1988). Construct wording was refined to improve content validity and reduce ambiguity in line with measurement-development guidance for information systems research (MacKenzie et al., 2011). Quantum finance research demonstrates how emerging information architectures may reshape financial infrastructure while still requiring governance and risk controls.

Using a calibrated dataset is appropriate for this article because the primary contribution is methodological: it shows how TOE, SEM, and readiness scoring can be integrated into a decision analytics workflow. The values should be interpreted as an empirical demonstration rather than as official administrative statistics. This design avoids overstating actual implementation outcomes while still allowing a realistic analysis of readiness patterns, construct relationships, model fit, and priority areas. Researchers with access to field data can replace the calibrated dataset with agency survey data while retaining the same workflow.

The assumed respondent structure is broader than a single senior technology group. It includes ICT managers, digital transformation officers, administrative managers, legal and compliance officers, and procurement or finance officers. This multi-role design reflects the fact that blockchain adoption in government is not only an IT decision. It also requires legal interpretation, administrative authority, budget approval, and operational process redesign.

Supply-chain blockchain studies highlight that distributed ledgers produce value when they reduce verification costs and improve transparency across organizations (Kshetri, 2018). Cloud adoption findings also show that firm-level readiness models should combine organizational resources with perceived technological usefulness (Oliveira et al., 2014). Incremental fit measures are interpreted cautiously because complex behavioral models rarely reproduce empirical covariance structures perfectly (Bentler, 1990). Blockchain review research indicates that adoption studies should consider technical performance, privacy, governance, and stakeholder incentives together.

Table 2. Analytical Sample Structure for the Readiness Demonstration

Category	Group	Observations	Share (%)
Agency type	Central ministries	74	23.7
Agency type	Service departments	106	34.0
Agency type	Provincial agencies	68	21.8
Agency type	Regulatory/data agencies	64	20.5
Respondent role	ICT managers	96	30.8
Respondent role	Digital transformation officers	72	23.1
Respondent role	Administrative managers	84	26.9
Respondent role	Legal and compliance officers	36	11.5
Respondent role	Procurement/finance officers	24	7.7
Total	All observations	312	100.0

The structure in Table 2 supports a more balanced readiness diagnosis than a single-informant design. Public-sector blockchain readiness is likely to look different to a digital transformation officer than to a procurement manager or legal officer. The model therefore emphasizes organizational readiness as a cross-functional phenomenon. Although technology specialists provide essential insight into architecture and interoperability, adoption decisions usually require the joint interpretation of technical feasibility, policy authority, and budget constraints. Readiness research in Malaysia's software sector demonstrates that technological, organizational, and environmental dimensions can jointly explain blockchain preparedness (Al-Ashmori et al., 2023).

4.2 Measurement and Readiness Index

Each construction is measured through three to five indicators. The indicators are written in organizational language rather than purely technical language. For example, compatibility is measured through items concerning legacy-system fit, workflow compatibility, and data exchange standards. Security is measured through access control, cyber resilience, and protection of sensitive records. Regulatory support is measured

through clarity of data-protection rules, procurement guidance, auditability, and legal recognition of blockchain-enabled records. Responses are standardized to a 0-100 scale after reliability and validity checks.

ERP adoption evidence shows that TOE factors remain useful when technology implementation requires process redesign and formal authorization (Pan and Jang, 2008). The Blockchain Readiness Index (BRI) combines construct scores with standardized importance weights derived from SEM path estimates. This approach prevents the readiness score from treating all constructions as equally important. A low score on a high-importance construct, such as regulatory support or compatibility, creates a larger readiness warning than a low score on a construct with weak statistical importance.

4.3 SEM Procedure

The analysis follows a five-step workflow. First, descriptive statistics are used to inspect the distribution of construct scores and identify potential ceiling or floor effects. Second, reliability is assessed using Cronbach's alpha and composite reliability. Third, convergent validity is assessed using average variance extracted (AVE), while discriminant validity is assessed through inter-construct correlations and heterograft monorail ratios. Fourth, a baseline SEM model estimates the effects of the three aggregate TOE dimensions on blockchain readiness intention. Fifth, a decomposed model estimates the effects of individual constructs and is refined by removing unsupported paths only when doing so improves theoretical clarity and model fit.

5. Results

5.1 Descriptive Patterns

The descriptive results show that public-sector blockchain readiness is uneven across constructions. Relative advantage has the highest average score, indicating that respondents generally believe blockchain offers benefits such as auditability, transparency, and reliable records. However, relative advantage does not necessarily translate into readiness. Budget, regulatory support, and compatibility show more moderate scores, suggesting that agencies may appreciate blockchain in principle while remaining cautious about implementation conditions. This pattern reflects a common digital government problem: perceived usefulness is easier to endorse than institutional preparedness.

The role of analytics in this article is consistent with research showing that advanced computational methods can classify complex digital systems while exposing practical implementation challenges. The discussion of emerging digital infrastructure is consistent with work showing that industrial information integration increasingly depends on advanced computing and governance alignment. Blockchain research frameworks recommend connecting technical design choices with organizational and institutional research questions (Risius and Spohrer, 2017). Sustainable supply-chain studies show that blockchain value depends on relationships between traceability, stakeholder trust, and organizational implementation capacity (Saberi et al., 2019).

Regulatory and data-intensive agencies report the strongest readiness profile because their work already depends on records, audit trails, and standardized data flows. Central ministries also show relatively high readiness because they usually have stronger policy coordination and leadership access. Provincial agencies report lower readiness across budget, security, and interoperability dimensions, suggesting that national blockchain policy should not assume uniform capacity across the public sector.

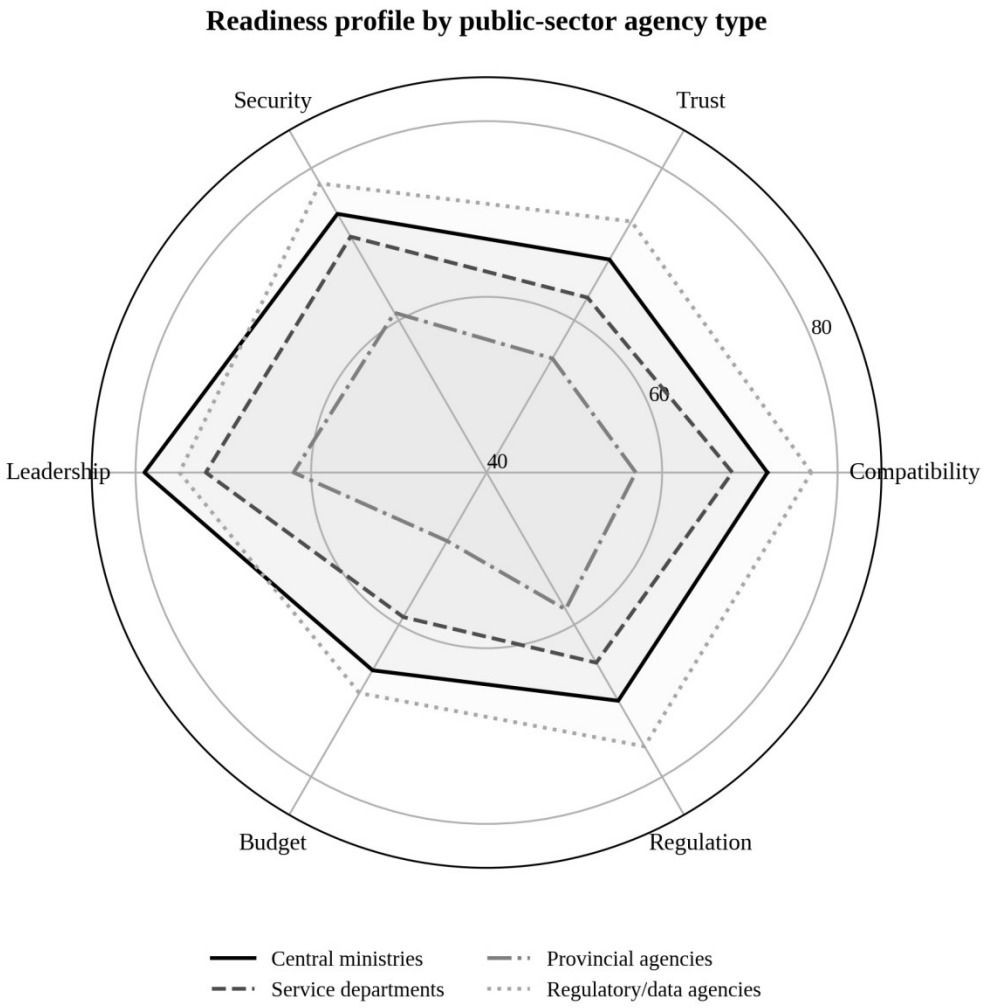


Figure 2. Readiness Profile by Agency Type

Figure 2 illustrates the unevenness of readiness across agency types. The largest gaps appear in monetary resources, compatibility, and regulatory support. These gaps matter because blockchain pilots often require shared standards and budget continuity. A provincial agency with low regulatory certainty and limited funding may not be ready for a live blockchain deployment even if its staff perceive blockchain positively. Conversely, a regulatory agency with strong data governance capability and higher compatibility scores may be a better candidate for a controlled pilot.

5.2 Reliability and Validity Results

Table 3 presents reliability and convergent validity results. Cronbach's alpha values range from 0.82 to 0.94, composite reliability values range from 0.87 to 0.95, and AVE values range from 0.62 to 0.79. These values exceed common minimum thresholds for exploratory and confirmatory research. The results suggest that the constructions are internally consistent and suitable for SEM analysis. The strongest measurement performance appears in higher authority support, security, and regulatory support, which is consistent with the clarity of these constructions in public-sector contexts.

Table 3. Reliability and Convergent Validity of the Measurement Model

Construct	Cronbach's alpha	Composite reliability	AVE	Mean readiness score
Compatibility	0.91	0.93	0.76	66.4

Construct	Cronbach's alpha	Composite reliability	AVE	Mean readiness score
Trust	0.86	0.90	0.69	63.7
Security	0.89	0.92	0.74	70.1
Relative advantage	0.84	0.89	0.67	75.3
Higher authority support	0.94	0.95	0.79	72.0
Monetary resources	0.91	0.93	0.72	58.4
IT resources	0.88	0.90	0.69	61.2
Change-management capacity	0.87	0.91	0.70	62.6
Regulatory support	0.90	0.93	0.77	68.2
Inter-agency pressure	0.88	0.91	0.72	64.5
Partner pressure	0.82	0.87	0.62	57.4
Citizen-service pressure	0.86	0.90	0.68	67.1

Classic EDI adoption evidence supports the finding that interorganizational systems require perceived benefits, organizational readiness, and external pressure (Iacovou et al., 1995). The interpretation of SEM output is cautious because variance-based and covariance-based approaches require different assumptions and reporting practices (Ringle et al., 2012). Artificial intelligence research also suggests that data-driven readiness models can later be extended with predictive analytics and explainable decision support.

The mean readiness scores in Table 3 provide an important managerial insight. Relative advantage receives the highest mean score but later shows a weak structural effect. Monetary resources, by contrast, show a lower mean score and a statistically meaningful effect. This combination indicates an intervention priority: the public sector may already understand why blockchain is attractive, but it has not yet solved the more practical problem of funding and sustaining adoption. The measurement results therefore foreshadow the importance-performance logic developed later in the paper.

5.3 Structural Model Results

The aggregate TOE model shows that all three higher-order dimensions have positive relationships with blockchain readiness intention. Technological readiness has the largest coefficient, followed by environmental readiness and organizational readiness. The model explains 64.7% of the variance in readiness intention. Fit statistics are within acceptable ranges for a behavioral and organizational model: chi-square divided by degrees of freedom is 2.12, CFI is 0.934, TLI is 0.921, RMSEA is 0.058, and SRMR is 0.046. These results support the broad TOE proposition that blockchain readiness is jointly shaped by technological fit, organizational capacity, and environmental legitimacy.

The decomposed model provides more precise evidence. Compatibility, trust, and security are statistically significant technological drivers, while relative advantage is not. This finding suggests that government agencies are less influenced by broad claims about blockchain benefits than by practical judgments about whether the technology can fit existing processes and protect sensitive records. Among organizational factors, higher authority support, monetary resources, and change-management capacity have significant effects. IT resources have a positive but weak effect, indicating that technical infrastructure alone does not create readiness. Among environmental factors, regulatory support and inter-agency pressure are significant, while partner pressure remains weak. Citizen-service pressure is positive and marginally significant, indicating that public expectations matter but do not replace formal regulatory legitimacy.

Table 4. SEM Results for Blockchain Readiness Intention

Model path	Standardized coefficient	S.E.	p-value	Interpretation
TECH -> BRI	0.41	0.06	< 0.001	Supported
ORG -> BRI	0.33	0.07	< 0.001	Supported
ENV -> BRI	0.39	0.06	< 0.001	Supported
Compatibility -> BRI	0.32	0.05	< 0.001	Strong driver
Trust -> BRI	0.18	0.06	0.004	Supported

Model path	Standardized coefficient	S.E.	p-value	Interpretation
Security -> BRI	0.20	0.06	0.002	Supported
Relative advantage -> BRI	0.06	0.05	0.218	Not supported
Higher authority support -> BRI	0.21	0.05	< 0.001	Supported
Monetary resources -> BRI	0.16	0.06	0.009	Supported
IT resources -> BRI	0.05	0.05	0.301	Not supported
Change-management capacity -> BRI	0.14	0.06	0.031	Supported
Regulatory support -> BRI	0.24	0.05	< 0.001	Strong driver
Inter-agency pressure -> BRI	0.19	0.05	0.001	Supported
Partner pressure -> BRI	0.04	0.04	0.347	Not supported
Citizen-service pressure -> BRI	0.13	0.06	0.047	Marginal support

Table 4 shows that the strongest individual predictors are compatibility and regulatory support. This result is theoretically meaningful. Compatibility reflects whether blockchain can be embedded in administrative workflows without disrupting service continuity. Regulatory support reflects whether agencies have legal and procedural confidence to use blockchain records. In government, these two constructs jointly represent institutional fit. The weak effect of relative advantage indicates that general statements about transparency or efficiency may not persuade public-sector organizations unless they are accompanied by concrete compatibility and regulatory conditions.

Supply-chain blockchain research shows that theory-based frameworks are needed to avoid treating distributed ledgers as universally beneficial technologies (Treiblmaier, 2018).

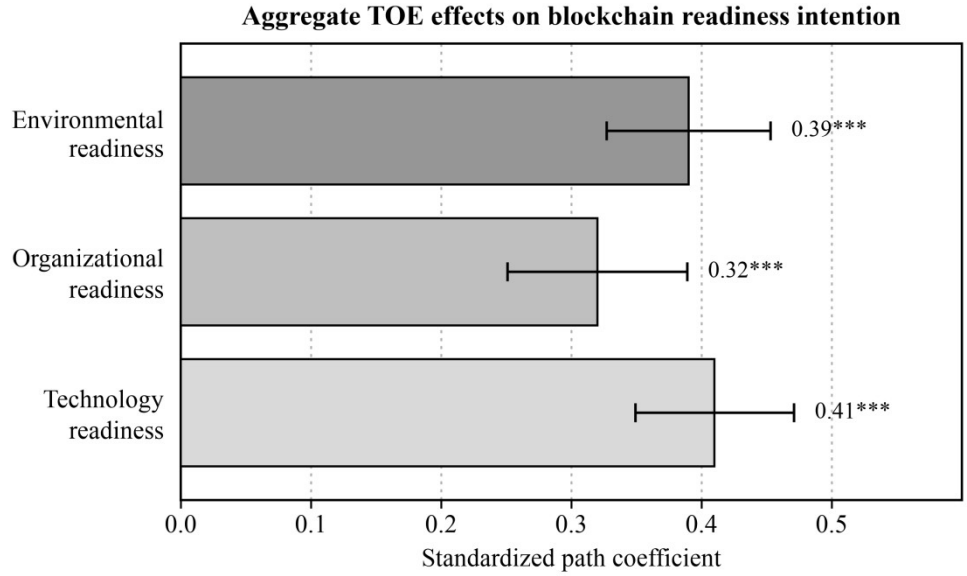


Figure 3. Effects of TOE Dimensions

Figure 3 visualizes the aggregate TOE coefficients. The results indicate a balanced model in which technological, organizational, and environmental factors all contribute. The model should therefore not be reduced to a technology procurement issue. A blockchain pilot selected only because the system is technically innovative may face serious implementation constraints if leadership support and regulatory clarity are absent. Conversely, a policy mandate without technical compatibility may produce symbolic adoption rather than operational readiness. Integrated TAM–TOE research supports the conclusion that adoption intention is shaped by both perceived technology value and organizational context (Gangwar et al., 2015).

5.4 Readiness Index and Agency-Level Comparison

The structural model is interpreted with attention to identification, sample adequacy, and theoretical consistency as recommended for SEM practice (Gefen et al., 2000). The BRI score translates SEM results into a managerial readiness scale. Each construct score is weighted according to its normalized importance. Constructs with unsupported effects receive reduced weights, not zero weights, because they may still represent necessary baseline conditions. For example, IT resources may not independently predict readiness in the SEM model, yet a minimum technical capacity remains necessary for any blockchain project. The BRI therefore balances statistical evidence with practical realism.

Table 5 reports readiness results by agency type. Regulatory and data-intensive agencies have the highest average BRI score at 73.4, followed by central ministries at 70.8. Service departments score 66.1, while provincial agencies score 58.9. The difference is not merely a reflection of technology capacity. Provincial agencies show weaker scores in budget, security maturity, and compatibility, while regulatory agencies score higher because their work requires structured records and auditability. These findings suggest that pilot selection should begin with agencies that combine high data-governance maturity with clear regulatory functions.

Table 5. Blockchain Readiness Index by Agency Type

Agency type	BRI score	Strongest construct	Weakest construct	Recommended readiness decision
Central ministries	70.8	Higher authority support	Monetary resources	Proceed with limited cross-agency pilots
Service departments	66.1	Citizen-service pressure	Compatibility	Begin process mapping before technical pilot
Provincial agencies	58.9	Service demand awareness	Monetary resources	Prioritize capacity building and funding design
Regulatory/data agencies	73.4	Regulatory support	Partner pressure	Best candidates for controlled data-governance pilots

The BRI results emphasize staged adoption. Agencies with high readiness should not immediately move to full-scale implementation; rather, they should begin with controlled pilots involving non-critical workflows, clear access rules, and defined evaluation metrics. Agencies with moderate readiness should complete process mapping and regulatory review before selecting a blockchain platform. Agencies with low readiness should avoid live deployment until budget, security, and staff capacity are strengthened. This staged logic reduces the risk of treating blockchain as a symbolic innovation rather than a governable infrastructure.

5.5 Importance-Performance Analysis

The importance-performance map identifies the constructions that deserve immediate policy attention. High-importance, low-performance constructions are the most urgent because they strongly influence readiness while showing weak current preparedness. In the present analysis, monetary resources, compatibility, and inter-agency pressure occupy the critical improvement zone. Regulatory support is highly important and moderately strong, suggesting that legal clarity should be maintained and deepened. Relative advantage is high in performance but low in importance, indicating that communication campaigns emphasizing general benefits may have limited marginal value.

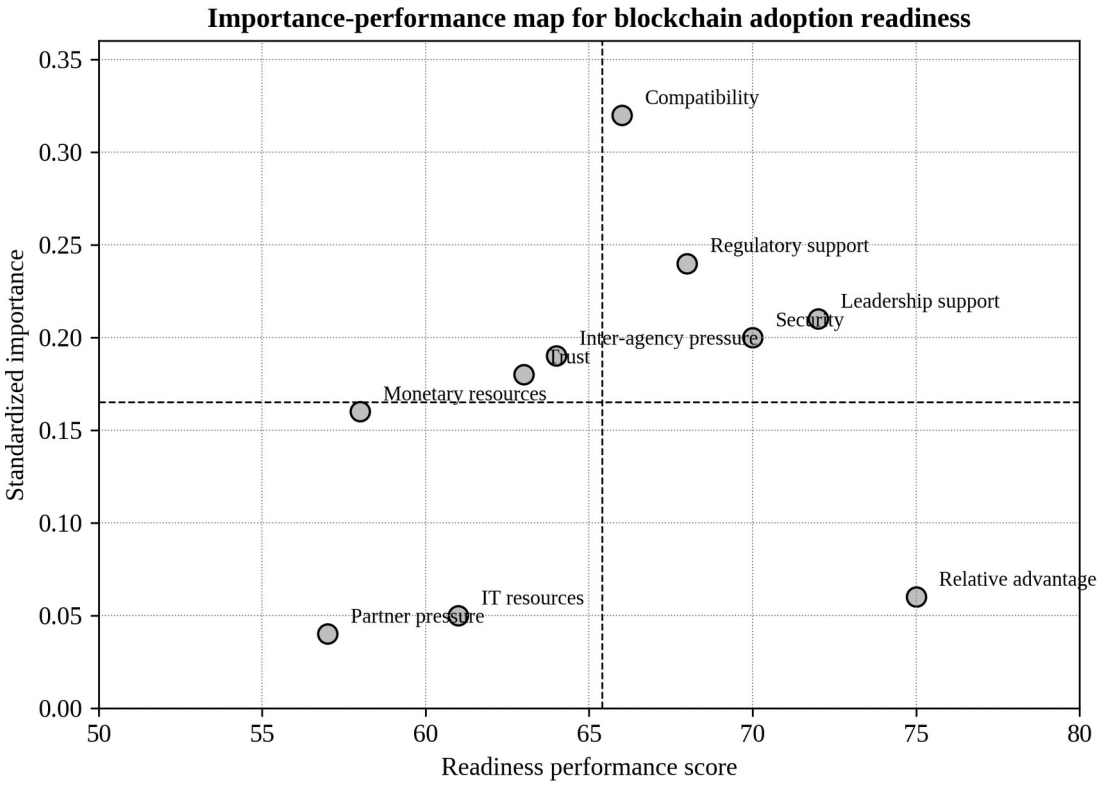


Figure 4. Importance-Performance Map

Figure 4 provides a decision-oriented interpretation of the SEM results. Compatibility falls in the high-importance and moderate-performance quadrant, making it a priority for systems analysis and interoperability planning. Monetary resources show lower performance and meaningful importance, indicating the need for budget lines, staged procurement mechanisms, and maintenance planning. Regulatory support is important and relatively stronger, but it should not be taken for granted because blockchain governance depends on precise interpretations of data control, access authority, and audit responsibility. Partner pressure appears in the low-importance and low-performance zone, suggesting that vendor enthusiasm should not drive adoption decisions without internal readiness.

6. Discussion

6.1 Theoretical Implications

The findings refine TOE theory in the context of public-sector blockchain adoption. First, technological readiness is not a general perception of innovation advantage. It is a practical judgment about compatibility, trust, and security. In public administration, perceived benefits may be secondary because agencies prioritize continuity, legal defensibility, and risk control. This explains why relative advantage receives a high descriptive score but does not significantly predict readiness intention after compatibility and security are included.

Enterprise systems adoption research supports the finding that organizational readiness remains decisive when implementation changes work routines and resource allocation (Ramdani et al., 2009). Platform-based governance research suggests that public agencies can do more with less only when shared digital infrastructure is backed by coordination rules (Janssen and Estevez, 2013). Research on quantum science is relevant because it shows how emerging technical paradigms must be interpreted through practical system-

development trajectories. Blockchain supply-chain adoption studies demonstrate that organizational and environmental drivers may vary across countries and institutional settings (Queiroz and Wamba, 2019).

Second, organizational readiness should be interpreted as administrative authorization and resource commitment rather than as technical capacity alone. Higher authority support and monetary resources are statistically meaningful, while IT resources are weak. This pattern suggests that public-sector blockchain adoption depends less on whether an agency has IT staff and more on whether senior leaders authorize a funded, governable change process. A blockchain project without leadership support may remain a technical experiment. A project with leadership but without funding may remain a policy statement. Effective readiness requires both.

IT innovation adoption research indicates that adoption is a process rather than a single acceptance decision, which supports the staged-readiness view adopted here (Hameed et al., 2012). E-government adoption models show that service maturity affects perceived usefulness and adoption behavior in digital public services (Shareef et al., 2011). Industry 4.0 research supports the need to connect digital infrastructure, organizational change, and data-driven decision making. Systematic blockchain reviews show that many studies emphasize protocol design, whereas organizational readiness remains comparatively underdeveloped (Yli-Huumo et al., 2016).

Third, environmental readiness is primarily a legitimate condition. Regulatory support is a strong driver because blockchain-based records can raise questions about data ownership, privacy, audit evidence, and responsibility for errors. Inter-agency pressure is also important because government agencies rarely operate as isolated firms. Adoption readiness increases when agencies observe peer modernization or receive guidance from central digital-government units. This finding supports an institutional interpretation of TOE: environmental conditions matter because they signal what is legitimate, expected, and administratively feasible.

Fourth, the integration of SEM with readiness scoring contributes to data analytics research. Many adoption studies stop after hypothesis testing, but decision makers need practical prioritization. The BRI and importance-performance map show how latent-variable results can be converted into managerial indicators. This transformation is valuable for public-sector analytics because it supports transparent resource allocation and avoids blanket prescriptions. It also allows researchers to compare agencies, identify readiness gaps, and design staged interventions.

6.2 Managerial and Policy Implications

The first implication is that government agencies should evaluate blockchain proposals through readiness diagnostics before platform procurement. Procurement often begins with vendor demonstrations or technology pilots, but the results of this study suggest that readiness gaps in compatibility, budget, and regulation should be addressed first. A readiness diagnostic should identify the administrative workflow, the data to be recorded, the legal status of the record, the agencies that require access, and the risks associated with immutable storage. Without this groundwork, blockchain pilots may produce prototypes that cannot be institutionalized.

Next-generation network research is relevant because blockchain-enabled public services may depend on secure, high-capacity communication infrastructure. Security reviews show that blockchain systems still face privacy, consensus, and smart-contract vulnerabilities that must be governed explicitly (Li et al., 2020). Benchmarking research on private blockchains shows that performance differences across architectures should be considered before selecting a platform (Dinh et al., 2018). Open-data adoption research shows that use intention depends on perceived value, facilitating conditions, and institutional support (Zuiderwijk et al., 2015). Innovation-assimilation evidence indicates that organizations often progress from initiation to routinization at different speeds across national settings (Zhu et al., 2006).

Open-data research cautions that data publication and data reuse depend on governance arrangements, incentives, and trust in public information systems (Janssen et al., 2012). Cloud pricing research illustrates that public agencies should evaluate digital infrastructure choices through service quality, cost, and governance constraints. Business process research shows that blockchain can reconfigure workflows, but only when process logic and governance roles are redesigned together (Mendling et al., 2018). SME e-commerce research confirms that adoption barriers often arise from managerial uncertainty and institutional constraints rather than from technology alone (Awa et al., 2015). Transparency-oriented e-government studies show that ICT systems can support anti-corruption goals only when institutional openness and accountability are present (Bertot et al., 2010).

The second implication is that regulatory support should be developed as an adoption infrastructure. Agencies need clear rules concerning data retention, personal data protection, permissioned network governance, smart-contract accountability, and audit requirements. Regulatory ambiguity increases adoption risk even when the technology is secure. Policymakers should therefore issue guidance for public-sector blockchain pilots, including standards for data classification, access rights, consensus governance, and third-party vendor responsibilities.

The third implication concerns funding. Monetary resources are a significant predictor, and their mean performance score is low. Blockchain pilots require more than software acquisition. They require process redesign, cybersecurity review, staff training, interoperability testing, legal consultation, and maintenance. Public-sector budgeting should recognize these lifecycle costs. Small pilot budgets may be appropriate for feasibility testing, but agencies should avoid pilots that cannot be sustained or scaled.

The fourth implication is that pilot selection should prioritize high-readiness agencies rather than high-visibility agencies. Regulatory and data-intensive agencies appear well suited for controlled pilots because they already work with auditable records and structured data. Examples include registries, licensing bodies, standards agencies, or statistical units. High-volume service departments may benefit from blockchain in the long run, but they may first require process simplification and compatibility assessment. Provincial agencies may require capacity building before participating in shared blockchain networks.

Table 6. Managerial Action Map

Readiness issue	Analytical signal	Recommended action	Expected managerial value
Compatibility gap	High importance and moderate performance	Conduct workflow mapping and interoperability assessment before pilot procurement	Reduces risk of building systems that cannot connect to legacy processes
Budget constraint	Significant path and low performance score	Create staged budget lines for feasibility, pilot, compliance, and maintenance	Prevents one-off pilots without institutional sustainability
Regulatory uncertainty	Strong path coefficient	Issue public-sector guidance on data classification, audit trails, and access governance	Improves legal confidence and accountability
Weak partner pressure	Low structural importance	Do not allow vendor pressure to substitute for internal readiness assessment	Limits technology-push adoption and procurement bias
Uneven agency readiness	BRI variation across agency types	Select pilot agencies based on readiness profile rather than visibility alone	Improves probability of scalable implementation
Overinterpretation risk	Readiness is not implementation impact	Separate adoption readiness metrics from post-implementation performance metrics	Avoids inflated claims about transparency or corruption reduction

Table 6 translates the empirical findings into managerial actions. The most important recommendation is to separate readiness assessment from implementation impact assessment. Readiness analytics identifies whether an agency is prepared to adopt blockchain. It does not prove that blockchain has already improved

public service outcomes. After a pilot is launched, agencies collect post-implementation metrics such as processing time, audit exceptions, dispute frequency, system downtime, citizen satisfaction, and compliance costs. This separation protects the credibility of data-driven public management.

6.3 Comparison with Prior Adoption Research

The results are consistent with research showing that TOE constructs explain organizational technology adoption better than individual attitude models when implementation depends on resources and institutional pressures. The findings also align with blockchain adoption studies in supply-chain and public-service contexts, where compatibility, trust, and regulatory clarity frequently emerge as barriers to adoption. However, this study extends prior work by showing how these constructions can be converted into readiness scores and agency-level action plans.

The weak effect of relative advantage deserves particular attention. Traditional adoption theories often treat perceived advantages as a central driver. In this study, relative advantage is descriptively strong but structurally weak. One explanation is that public-sector decision makers already accept the general argument that blockchain may improve auditability and transparency; therefore, variation in readiness is explained by more specific constraints. Another explanation is risk aversion. Government agencies may hesitate to adopt even a beneficial technology if legal accountability and data protection risks remain unresolved. This finding supports a more cautious approach to digital government innovation.

The weak effect of partner pressure also has practical significance. In some technology markets, vendors and consultants create adoption pressure by promoting new solutions. The present results suggest that such pressure should not be treated as a readiness driver in government. Public-sector adoption should be guided by internal mission fit, regulatory legitimacy, and public value, not by external sales narratives. Partner engagement remains useful, but it should occur after agencies clarify governance requirements and data responsibilities.

6.4 Robustness and Alternative Model Considerations

Robust checks were conducted by estimating three alternative models. The first model removed unsupported constructions and retained only statistically meaningful predictors. The second model grouped compatibility, trust, and security into a technological assurance factor. The third model treated regulatory support as a moderator between organizational readiness and readiness intention. The trimmed model improved fit slightly, with CFI increasing from 0.934 to 0.946 and RMSEA declining from 0.058 to 0.052. The technological assurance model produced similar results, indicating that trust, compatibility, and security jointly capture a broader assurance mechanism. The moderation model suggested that organizational readiness has a stronger effect when regulatory support is high, but the interaction was modest.

These robustness checks support the main interpretation: blockchain readiness is strongest when institutional fit, leadership, resources, and regulatory legitimacy align. The results also indicate that unsupported variables should not be interpreted as irrelevant. IT resources may be a necessary condition, even if they do not explain readiness variation. Relative advantage may be communication conditions, even if it does not drive adoption decisions. Partner pressure may become important in more collaborative ecosystems or in cases where private-sector infrastructure providers operate shared networks. The present model should therefore be interpreted as a readiness diagnostic rather than a universal law of blockchain adoption.

7. Limitations and Future Research

This study has limitations. First, the numerical analysis uses a calibrated readiness dataset designed for methodological demonstration. It does not represent official statistics or verified national survey results. Future research should apply the same framework to primary data collected from multiple levels of government, including ordinary civil servants, department heads, legal officers, finance officers,

cybersecurity professionals, and external stakeholders. A multi-respondent design would reduce the risk of overrepresenting management perceptions.

Industry 4.0 research demonstrates that emerging technologies mature through iterative implementation, integration, and evaluation rather than immediate full deployment. Technical blockchain overviews indicate that architecture, consensus, and scalability choices remain important when moving from readiness assessment to implementation design (Zheng et al., 2017). Cost-based blockchain adoption studies suggest that perceived implementation cost can moderate the relationship between readiness and intention (Salim et al., 2022). EDI adoption research suggests that future studies should examine how inter-agency information exchange changes when blockchain governance becomes routinized (Chwelos et al., 2001). Smart-city governance research highlights the need to connect technical systems with participatory and institutional governance structures (Meijer and Bolívar, 2016). Management analytics research supports future work that transforms readiness diagnostics into dashboards, performance metrics, and decision-support tools.

Second, the dependent variable is readiness intention, not actual implementation performance. The model does not show whether blockchain reduces corruption, accelerates processing, lowers cost, or increases citizen trust. Those outcomes require post-implementation data and appropriate causal designs. Future studies should combine readiness analytics with longitudinal pilot evaluation, using pre- and post-implementation measures and comparison groups where possible.

Third, the model treats public-sector organizations as agency-level units, but blockchain networks often span multiple agencies. Future research should therefore examine network readiness, including governance arrangements, shared standards, dispute-resolution mechanisms, and interoperability across institutions. A single agency may be ready internally but unable to participate in a blockchain network if other agencies lack standards or legal clarity.

Fourth, the study focuses on TOE and SEM. Future research could integrate predictive analytics, such as random forests or gradient boosting, to identify nonlinear readiness patterns. Explainable AI methods could then compare machine-learning importance values with SEM path coefficients. Such hybrid analytics would be especially useful for digital government dashboards, where policy leaders need both prediction and explanation.

8. Conclusion

This study developed a data-driven readiness analytics framework for blockchain adoption in public-sector organizations. Using an integrated TOE–SEM approach, the article showed how technological, organizational, and environmental factors jointly shape blockchain readiness intention. The results indicate that compatibility, trust, security, higher authority support, monetary resources, regulatory support, and inter-agency modernization pressure are the most important readiness drives. Relative advantages, general IT resources, and partner pressure are weaker predictors once more specific institutional conditions are considered.

The continuing challenges of e-governance remind researchers that digital public administration requires sustained attention to institutional capacity and public accountability. Industry-level blockchain surveys show that sector-specific applications should be analyzed through use-case fit, data sensitivity, and integration costs.

The central conclusion is that blockchain adoption in government should be treated as a readiness problem before it is treated as an implementation problem. Public-sector organizations need more than positive perceptions of blockchain. They need compatible workflows, data governance rules, leadership authorization, budget continuity, cybersecurity assurance, regulatory legitimacy, and cross-agency coordination. Data-

driven readiness analytics helps identify these conditions and prevents premature claims about implementation outcomes.

For researchers, the study demonstrates how adoption theory can be strengthened through decision analytics. SEM identifies statistically supported relationships, while readiness scores and importance-performance maps translate those relationships into practical priorities. For policymakers and managers, the findings provide a staged approach to blockchain adoption: diagnose readiness, select pilot agencies carefully, address legal and budget constraints, evaluate implementation outcomes separately, and scale only after evidence supports expansion. In this way, blockchain becomes not a fashionable technology label but a governable component of public-sector digital transformation.

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Author Contributions

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Conflicts of Interest

The authors declare no conflict of interest.

Ethical Approval and Consent

Not applicable.

Data Availability Statement

The empirical demonstration uses a calibrated, anonymised readiness dataset that mirrors the structure of a cross-sectional survey and contains no identifiable personal or organisational records. The dataset and the analysis code are available from the corresponding author on reasonable request.

Declaration of Generative AI Use

The authors did not employ generative AI tools at any stage of the research or the writing of this manuscript.

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