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Research Article

STRUCTURE AND PRIORITY OF STRATEGIC FACTORS IN INDONESIAN REAL-WORLD ASSET TOKENIZATION: AN ISM–MICMAC APPROACH

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ABSTRACT

Background: Real-world asset (RWA) tokenization has entered implementation in Indonesia ahead of a comprehensive regulatory framework, leaving regulators and the industry without a structured basis for ordering interventions.
Purpose: This study models the structure and priority of the strategic factors for RWA tokenization in Indonesia. "Priority" denotes a factor's position in an expert-elicited influence hierarchy and its driving power, not an estimated policy effect.
Design/methodology/approach: Using a Technology–Organization–Environment (TOE) framing, this study applies Interpretive Structural Modeling (ISM) and cross-impact matrix multiplication applied to classification (MICMAC) to pairwise judgments from a purposive panel of four experts (regulator, industry issuer, IT and cybersecurity practitioner, and blockchain academic). Fifteen factors were aggregated by majority rule (at least three of four). Seventeen of 105 pair decisions were set by the research team rather than by majority; one of them, the treatment of the F1–F14 relation (coded mutual by three experts and analytically resolved so that F14 does not influence F1), determines whether an informative hierarchy exists. Sensitivity analyses cover alternative F1–F14 codings, per-expert reruns, leave-one-out aggregates, alternative tie rules, and MICMAC midpoints. The model reflects expert judgment, not observed policy effects.
Findings: Under the analyst-resolved convention, the aggregate model has ten levels, with regulatory clarity (F1) as the single root and user adoption (F15) as the single terminal factor; privacy, smart-contract quality assurance, and cybersecurity (F4, F5, F6) form a mutually reachable set. At the conventional 7.5 midpoint, no factor falls in the Linkage quadrant, and stakeholder coordination (F14) is dependent (driving power 2, dependence 13). These positions hold in leave-one-out aggregates that share the convention. They do not hold if the experts' mutual F1–F14 coding is retained (the structure collapses into a thirteen-factor cycle) or if the midpoint is set at 7 (F7, F8, and F9 become Linkage factors).
Conclusion: The ordering is best read as a set of provisional sequencing priorities, conditional on the coding convention and midpoint, rather than as verified causal necessities. It suggests consolidating regulatory and legal foundations before downstream market-infrastructure and adoption measures and leaves open whether early stakeholder coordination is ineffective.
Originality/value: To the authors' knowledge, this is the first expert-elicited structural model of RWA tokenization enabling factors at the ecosystem level. The contribution is contextual and methodological: it reports, alongside the results, the decisions that shape the hierarchy. It introduces no new construct; at the factor level, it suggests that, in a pre-regulatory emerging-market ecosystem, regulatory clarity occupies the base position, while the environment dimension, which also contains dependent factors, does not lead as a unit.

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INTRODUCTION

Separating ownership rights and economic claims from the physical form of an asset is an enduring function of financial systems: land titles, share certificates, and gold deposit receipts each detach a claim from its underlying object so that ownership can be proven, transferred, and traded (World Economic Forum, 2025). Conventional instruments imperfectly discharge this function. Their validity depends on a central recording authority, and transfer is slow and costly because it passes through multiple intermediaries. Moreover, high-value assets

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are difficult to divide into smaller units, constraining accessibility and liquidity and keeping entry barriers high for smaller investors (Proskurovska & Birch, 2025). Blockchain, as a form of distributed ledger technology, relaxes these constraints by representing ownership as digital tokens that are transparent, difficult to manipulate, divisible, and transferable directly between parties without a central intermediary (Bayan et al. 2025). When the tokenized object is a real-world asset (RWA) such as gold, property, or security, this practice becomes RWA tokenization (Benedetti & Rodriguez-Garnica, 2023), which is, in effect, the digital extension of securitization to illiquid assets (Proskurovska & Birch, 2025).

The economic stakes are substantial rather than speculative. Even under a scenario described as conservative, the global value of tokenized assets is projected to reach roughly USD 16 trillion by 2030, about 10% of global GDP (Boston Consulting Group & ADDX, 2022). Capturing this potential, however, is not a purely technical matter. RWA tokenization is a cross-dimensional undertaking whose effectiveness depends jointly on the strength of the legal bond between a token and its underlying asset (Lavayssière, 2025), on governance and the distribution of risk across parties (Tanveer et al. 2025), and on containing an expanded attack surface that spans smart-contract flaws, key compromise, and interoperability weaknesses (Bayan et al. 2025; Zhao et al. 2025). These dimensions interact rather than sum; weakness in one can neutralize strength in the others; therefore, it is the configuration of factors, not merely their presence, that governs whether tokenization delivers its promised gains. For this reason, tokenization is widely held to demand adaptive institutions and regulation, not technological readiness alone (Tanveer et al. 2025).

Indonesia presents an unusually sharp instance of this challenge because implementation has run ahead of the comprehensive regulation. Under the innovation-sandbox mechanism established by POJK 3/2024 on financial-sector technology innovation, four entities graduated from the OJK Sandbox by March 2026 across three distinct business models: gold (GIDR), government securities (IDDB), and property (GORO), signaling that RWA tokenization had entered real implementation (Bisnis.com, 2025, 2026; Kontan, 2025; Nanovest, 2024; OJK, 2024a). Market demand has formed in parallel: the national crypto-asset consumer base reached 19.56 million by November 2025 (Saputra, 2026, reporting OJK data). However, a comprehensive tokenization framework is still being developed. A draft OJK regulation on Digital Financial Asset Offerings, which covers tokenized assets, was released for public consultation on September 19, 2025, and remained unfinalised as of the most recent source consulted for this manuscript (OJK, 2025a; SSEK Legal Consultants, 2025). Because the enabling factors are mutually dependent, an improvement in one does not become effective while prerequisites in another remain unmet. This leaves regulators to set policy priorities without an evidentiary basis for ordering them, and industry actors exposed to premature scaling; intervention that is not priority-based risks policy inefficiency, duplicated system strengthening, and a failure to build durable market trust.

The factors that shape RWA tokenization implementation have been identified, but largely in isolation, spanning economic benefits and risks (Benedetti & Rodriguez-Garnica, 2023; Tanveer et al. 2025), legal structure (Lavayssière, 2025), technical security and design (Bayan et al. 2025; Zhao et al. 2025), and adoption determinants (Misztal, 2026). What remains contested is not whether these factors matter but how they are organized: which factors drive others, how influence propagates through the system, and in what order intervention should proceed. A recent large-scale review of blockchain adoption explicitly names the interdependence and multidimensionality of adoption factors as an unresolved direction for research (Zhang et al. 2024), indicating that partial identification has reached its explanatory limit. Adjacent work confirms that the space is active rather than empty: RWA tokenization in Indonesia has been examined in legal-descriptive terms (Oudang et al. 2026; Utomo et al. 2025), expert-based prioritization of tokenization factors has been carried out with AHP for security token offerings (Lee et al. 2025), and ISM–MICMAC has been applied to an Indonesian digital-finance ecosystem in WealthTech (Siregar et al. 2025). Each of these differs from the task at hand in method or scope: assigning weights rather than reconstructing structural interdependence, or treating a single asset class or offering type rather than a cross-asset enabling ecosystem. None, however, models the driving–dependence interdependence among factors at the enabling-ecosystem level of RWA tokenization. In a setting where implementation precedes regulation, closing this gap carries direct policy consequences rather than academic interest alone.

Accordingly, this study asks: How are the strategic factors enabling RWA tokenization in Indonesia structurally ordered in an expert-elicited model, and which factors are positioned as foundations, intermediaries, and dependent outcomes? Drawing on a technology–organization–environment (TOE) framing and an elicitation panel of four domain experts, it applies interpretive structural modeling (ISM) to reconstruct the hierarchy of interdependence and MICMAC analysis to classify factors by driving and dependence power. Here, "priority" has a defined meaning: a factor has higher priority when it is positioned lower in the hierarchy and has higher driving power, that is, when the experts' judgments place it as enabling more of the other factors. This does not mean greater importance, larger effect, or higher return. The model can support a description of how four experts' judgments, once aggregated and closed under transitivity, are structured and a provisional sequencing heuristic derived from it. It cannot support an estimate of policy effects, a causal claim, or a claim about a panel other than this one. The contribution is deliberately bounded. Empirically and methodologically, the study offers what is, to our knowledge, the first expert-based structural model of enabling-ecosystem factors for RWA tokenization, and it reports the decisions that shape the hierarchy (the aggregation exceptions, the F1–F14 convention, the expert-level and leave-one-out checks, and the midpoint sensitivity) together with the four expert matrices and the reachability matrices. Conceptually, it suggests a boundary-condition refinement rather than a new construct: in a pre-regulatory emerging-market ecosystem, regulatory clarity may occupy the base position, in tension with the technology-centric emphasis common to blockchain-adoption research. Practically, the model gives regulators and industry a provisional basis for sequencing interventions, to be tested rather than assumed.

METHODS

This study employs an exploratory qualitative design that combines interpretive structural modeling (ISM) with cross-impact matrix multiplication applied to classification (MICMAC) analysis. ISM was used to build a hierarchical model of the contextual relationships among strategic factors from expert judgment, and MICMAC was used to classify those factors by their driving power and dependence power. The design is interpretive rather than inferential: the numeric structures it produces are relational, binary representations of expert reasoning, not statistical estimates, so its adequacy rests on the transparency and auditability of the elicitation and modeling procedure rather than on sample-based generalization. Fieldwork was conducted between January and April 2026 across DKI Jakarta and Kota Bogor, with primary data collected in March 2026. The empirical setting is the ecosystem for Real World Asset (RWA) tokenization in Indonesia during its early, sandbox-mediated phase, in which implementation has run ahead of a comprehensive regulatory framework. Reporting follows the APA Journal Article Reporting Standards for qualitative research (JARS-Qual; Levitt et al. 2018), and the interview components are reported in line with the Consolidated Criteria for Reporting Qualitative Research (COREQ; Tong et al. 2007).

Expert informants were selected purposively on the basis of role relevance and competence relative to the RWA tokenization ecosystem (Sugiyono, 2023). Four experts were engaged, chosen to represent the key actor nodes of the ecosystem under the Technology–Organization–Environment (TOE) framework: a regulator for the environment dimension (N1, the financial-sector regulator unit responsible for digital financial innovation); an industry issuer for the organization dimension (N2, the chief executive of a sandbox-graduated gold-tokenization issuer); an information-technology and cybersecurity practitioner for the technology dimension (N3, the founder of a blockchain and cybersecurity consultancy); and an academic technologist, also for the technology dimension (N4, a professor of blockchain and artificial intelligence heading a university research center). Informants are identified by role and code in this version of the manuscript. The IT practitioner and the academic technologist were kept as separate informants deliberately, so that the technical dimension would be assessed with sufficient depth, while the regulator secured the policy dimension that is the critical context for implementation in Indonesia.

The panel size of four is grounded in the expert-based logic of ISM–MICMAC rather than in statistical sampling adequacy: validity is determined by the quality and representativeness of the experts' knowledge, not by the number of informants. ISM is designed to help a small group of experts build a structural model of a complex system from their contextual knowledge (Attri et al. 2013), and reviews of ISM applications

report that the number of decision-makers used varies widely, from 2 to 120 (Ahmad & Qahmash, 2021); a four-expert panel therefore falls within an established and defensible range. The characteristics of the four informants, the basis of their expertise, and the conduct of each interview are summarized in Table 1.

Coverage of the panel is uneven, and this is stated rather than assumed away. Legal and licensing issues are covered through the regulator (N1). Issuance, custody, and market-facing operations are covered through the industry issuer (N2) and, indirectly, through N1. Technical and security issues are covered through N3 and N4. Two areas are covered only indirectly: custodian and trading-venue operators (relevant to F10, F11, and F12) are represented through N1 and N2 rather than by custodian or exchange representatives, and user adoption (F15) is represented through experts' perceptions rather than investor-side evidence. The panel is therefore sufficient for a structural reading of how experts see the ecosystem across legal, technical, and market domains, and insufficient as evidence on custody practice or investor behavior; this limitation is carried into the interpretation of F10, F11, F12, and F15.

Researcher Positionality

Reflexivity requires disclosure of the research team's relationship to the field. One member of the research team has a prior professional association, predating this study, with the institutional unit that served as informant N1 (the nature of the association is stated on the title page rather than in the body of the manuscript, in line with the journal's double-blind policy). This prior association creates a potential conflict of interest and a risk of bias toward the regulator's perspective, a risk compounded by the domain-priority tie-break rule (Section: Aggregation, ISM, and MICMAC analysis), which privileges the regulator on regulatory pairs.

Several safeguards were applied. Majority-rule aggregation across the four experts means that no single informant determines the 89 majority-coded pairs; the rule applied to every non-majority pair is recorded in Appendix A; each expert validated the factor set and their own inputs; and divergent perspectives were retained rather than reconciled away. One limit must be stated plainly: the F1–F14 convention follows the regulator's coding, so on that pair the regulator's view does determine the result, and the sensitivity analyses (Findings) show that this single decision is the one on which the hierarchy depends. The Sensitivity analyses subsection of the Findings reports a data-based check of how far the central structural claims depend on any single informant's judgment.

Factor Development and Validation

Candidate factors were derived from the systematic literature synthesis reported in the Conceptual and Theoretical Framework, yielding 22 candidates that were then curated to 15 strategic factors (F1–F15) using four selection criteria: (1) direct relevance to RWA tokenization at the ecosystem level; (2) non-overlap with other factors at the level of operational definition; (3) practical assessability within an expert interview; and (4) relevance to the Indonesian context, characterized by transitional regulation, a retail-dominated market, and an early-stage ecosystem. Curation was guided by the TOE requirement that all three contexts be represented, deliberately counterbalancing the technology-dimension skew typical of the tokenization and blockchain-adoption literature (Dehghani et al. 2022; Bhat et al. 2025). During the interviews the experts confirmed the relevance and definitional clarity of the 15 factors and stated that no important factor had been omitted; definitions were refined in wording where experts suggested improvements, without altering the substance of any factor. The operational definition of each factor is reported in Table 2.

Data Collection and SSIM Elicitation

Primary data were gathered by the researcher (first author) through a single in-depth interview with each expert, conducted in hybrid form: N1 across online and on-site sessions, N2 and N3 online, and N4 on site (Table 1). Each interview served two linked purposes: validating the relevance and definitions of F1–F15, and eliciting the contextual relationships among factors for the Structural Self-Interaction Matrix (SSIM). To reduce cognitive load and maintain consistency, the researcher supplied a one- to two-sentence definition card for each factor and organized the discussion by TOE-grouped factor pairs. For each of the 105 unique factor pairs (i, j), the expert assigned one of four SSIM symbols: V, if factor i influences factor j; A, if factor j influences factor i; X, if the two factors influence each other mutually; and O, if the two factors are unrelated.

Table 1. Profile of the expert informants

Code	Informant (role-based description)	Role (TOE dimension)	Basis of expertise	Interview date (2026)	Mode and setting
N1	Financial-sector regulator, digital financial innovation unit	Regulator (Environment)	Unit responsible for developing and supervising digital financial innovation, including the regulatory sandbox that is the entry point for RWA tokenization in Indonesia	21–22 March	Hybrid: online (Zoom) and in person (regulator's office)
N2	Sandbox-graduated gold-tokenization issuer (chief executive)	Industry issuer (Organization)	Leads a gold-tokenization venture that has completed the regulatory sandbox; operational perspective of an issuer	5 March	Online (Zoom)
N3	Blockchain and cybersecurity consultancy (founder)	IT practitioner (Technology)	Blockchain practitioner focused on system development and technical-security aspects; technical implementation perspective	5 March	Online (Zoom)
N4	University blockchain and AI research center (head, professor)	Academic technologist (Technology)	Professor and blockchain expert heading an AI-and-blockchain research center; academic-conceptual perspective on the technology	6 March	In person (research center office)

Table 2. The fifteen strategic factors, TOE dimension, and operational definitions

Code	Factor	TOE	Operational definition
F1	Regulatory clarity & licensing	Environment	Clarity of activity classification, licensing, and supervisory scope for RWA tokenization
F2	Legal enforceability (token–asset legal bond)	Environment	Strength of the token–asset legal bond so that token-holders' rights are enforceable
F3	Compliance architecture (KYC/AML/identity)	Organization	Integrated KYC/AML/identity design across onboarding, transactions, and audit
F4	Privacy & data protection	Environment	Data-protection and privacy mechanisms compatible with auditability and compliance
F5	Smart contract quality assurance	Technology	Maturity of audit, verification, testing, and change-control processes for smart contracts
F6	Cybersecurity & key management	Technology	System resilience against attack and implementation of standardized security controls
F7	Oracle & data integrity	Technology	Reliability of data integration and the mechanisms that safeguard underlying-data integrity
F8	Scalability & performance	Technology	Throughput, latency, and transaction-cost capability as volume grows
F9	Interoperability & standards	Technology	Cross-system and cross-network capability and use of token standards for ecosystem integration
F10	Custody & safeguarding model	Organization	Readiness of the custodian model and safeguarding of assets and holder rights
F11	Market infrastructure readiness	Environment	Readiness of trading venues, listing rules, surveillance, clearing/settlement, and market conduct
F12	Liquidity & price discovery	Environment	Market depth and price-formation mechanisms that reflect underlying conditions
F13	Governance & accountability design	Organization	Governance design that prevents the concentration of power
F14	Stakeholder coordination & ecosystem alignment	Organization	Coordination among stakeholders for standardization, SOPs, and process integration
F15	User adoption, trust & literacy	Organization	Level of market acceptance underpinned by trust, literacy, and risk/benefit perception

Aggregation, ISM, and MICMAC Analysis

A single aggregate SSIM was constructed from the four expert matrices by majority rule: for each of the 105 upper-triangle pairs, a symbol adopted by at least three of the four experts (at least 75%) was retained. Ninety-two pairs reached this threshold. Three of them (F4–F5, F4–F13, F4–F14) were then set against the majority on substantive grounds noted in Appendix A, so 89 pairs (84.8%) stand as majority-coded. The remaining thirteen pairs split two to two and were resolved by a domain-priority principle (the regulator for pairs concerning regulation, legality, or compliance; the industry and technical experts for predominantly technical-operational pairs). The outcomes do not map uniformly onto that principle: of the nine tie pairs involving F1, F2, or F3, six were not resolved to the regulator's symbol. We therefore do not treat the principle as determinative, and we test alternative tie rules in the sensitivity analyses. Appendix A records, for each of the sixteen pairs, the four expert symbols, the aggregate symbol, and the rule applied. No pair-level rationale beyond that rule was documented at the time of aggregation, so the resolutions are treated as research-team decisions whose consequences are tested rather than defended. Counting the F1–F14 decision described next, seventeen of 105 pairs (16.2%) rest on decisions of the research team rather than on a majority, and readers should weigh the structure accordingly.

Inter-expert agreement is reported alongside these figures rather than inferred from the majority rate: the four experts agreed unanimously on 61 of 105 pairs (58.1%), and Fleiss' kappa across the four V/A/X/O categories was 0.539, conventionally read as moderate agreement. Pairwise agreement ranged from 69.5% (N1–N4) to 83.8% (N2–N3). The aggregate SSIM was converted into an initial reachability matrix (IRM) by binary coding of the V/A/X/O symbols, and full transitive closure was applied to obtain the final reachability matrix (FRM), such that if factor i reaches j and j reaches k, then i is taken to reach k (Ahmad & Qahmash, 2021; Sushil, 2017).

Cycle-resolution decision on F1–F14. This is the pivotal decision of the study and is stated separately from the sixteen exceptions above. Three of four experts (N2, N3, N4) coded regulatory clarity (F1) and stakeholder coordination (F14) as mutually influencing (X); the regulator (N1) coded F1 as influencing F14 (V). Under full closure, retaining X merges thirteen of the fifteen factors into one strongly connected component, leaving a three-level structure in which thirteen factors share identical coordinates and the MICMAC map is uninformative. Coding the pair A (F14 influences F1) produces the same collapse, because F14 is influenced by most other factors. Coding the pair O produces the same hierarchy as coding it V, because F1 already reaches F14 through other factors (for example F3). The adopted convention, that F1 influences F14 and F14 does not influence F1, is therefore equivalent to suppressing the F14-to-F1 influence that three experts reported. It follows N1's coding. It is an analytical convention required to obtain a hierarchy, not a panel majority and not a direction endorsed by the experts: in the interviews, N2, N3, and N4 described the relation as two-way.

Reachability and antecedent sets were computed from the FRM, and iterative level partitioning produced the hierarchical ISM model (Figure 1). For MICMAC, each factor's driving power (its FRM row sum) and dependence power (its FRM column sum) were derived from the same FRM, plotted on a two-dimensional map, and classified into autonomous, dependent, linkage, and driver clusters against the scale midpoint of 7.5, half of the 15 factors (Yadav & Desai, 2017). Because several factors lie within one unit of 7.5, midpoints from 6 to 9, the mean driving power (7.87, equal to mean dependence because row and column sums are equal), and the median (7) were also examined.

Sensitivity and Robustness Analyses

Because the aggregate structure rests on a majority-rule threshold of three of four experts, on seventeen decisions of the research team, and on a disclosed association between one team member and the regulator informant's unit, five sets of analyses were run, each repeating the complete computation (IRM, transitive closure, level partitioning, MICMAC). First, the F1–F14 relation in the aggregate was coded in each of four ways (X, A, O, V). Second, the computation was run separately on each expert's own SSIM, both with the expert's own F1–F14 code and with the convention imposed. These are expert-level recomputations and should not be read as leave-one-out analyses. Third, genuine leave-one-out aggregates were built: one expert was omitted, the remaining three were aggregated by simple majority (two of three, with unresolved pairs coded O and no manual overrides), and the computation

was run with the F1–F14 relation pooled as coded and with the convention applied. Fourth, the aggregation rules were varied: ties coded O, ties following N1, ties following N1 only when N2 agrees, and no overrides of the majority. Fifth, MICMAC midpoints from 6 to 9 were examined.

These analyses can show whether the central positions (root, terminal factor, quadrant of F14, empty Linkage quadrant) depend on a single expert, on the tie and override rules, on the F1–F14 convention, or on the midpoint. They cannot show that a different panel would recover the same structure, and analyses that share the F1–F14 convention cannot show robustness to retaining the experts' mutual coding; that limit is inherent to expert-based structural modeling and is not resolved by internal consistency.

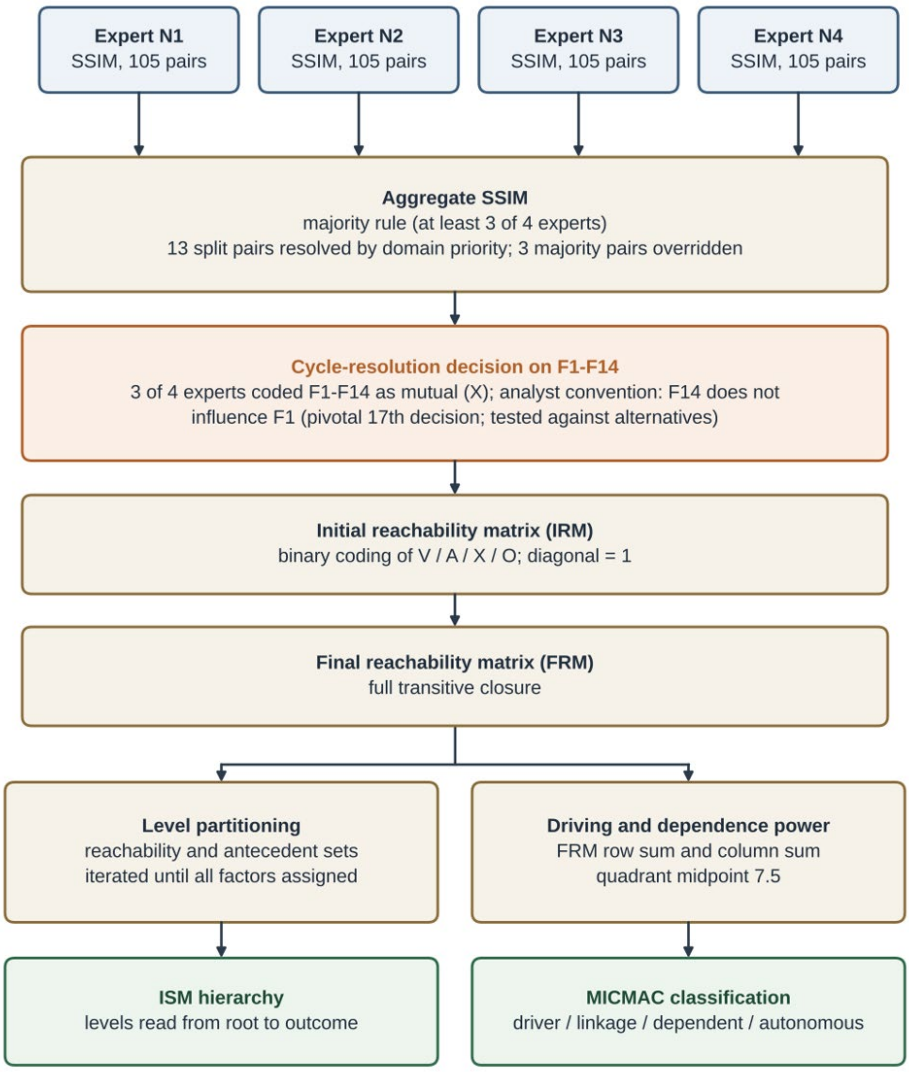

Figure 1. Analytical pipeline from expert elicitation to the ISM hierarchy and MICMAC map (The figure sets out the sequence of transformations described in this section; it reports no results. Each expert supplied one Structural Self-Interaction Matrix covering all 105 pairwise relations among the fifteen factors. The four matrices were reduced to a single aggregate SSIM by majority rule, with tie pairs resolved by domain priority and three majority pairs overridden. The F1–F14 relation was then resolved by an analytical convention (Method). The aggregate SSIM was binary-coded into the initial reachability matrix, transitive closure produced the final reachability matrix, and two outputs were derived from it: the hierarchy by iterative level partitioning, and the MICMAC classification from row and column sums. All computations were run with a documented script; sensitivity analyses repeat the pipeline under alternative assumptions).

Trustworthiness

Rigor was pursued through an auditable chain of evidence rather than statistical validation. Member validation was obtained from all four experts, who confirmed or signed off on their inputs; documented corrections (fifteen symbol corrections logged with N1 and five typographical corrections aligned with N3) and the rule applied to every non-majority or overridden pair, listed in Appendix A, together constitute the audit trail. Analytic transparency was pursued by reporting the four expert SSIMs, the aggregate SSIM, the reachability matrices, and the level-partitioning iterations, so that every reported value can be recomputed; the script used for the computation is provided as a supplementary file (ism_rwa_replication.py), which embeds the validated expert matrices and regenerates the hierarchy, the MICMAC coordinates, and the sensitivity analyses. The expert-level reruns and the leave-one-out aggregates are reported separately and are not interchangeable (Sensitivity analyses). Transferability is supported by the description of the experts and the setting (Table 1), which lets readers judge the contexts to which the resulting structure may reasonably apply.'

Conceptual and Theoretical Framework

Real-world asset (RWA) tokenization refers to the conversion of rights over tangible or financial assets (property, commodities, or securities) into digital tokens recorded on a blockchain or distributed ledger, where each token represents an enforceable economic or ownership claim over an underlying asset (Lavayssière, 2025; Mirdala, 2025). The ledger's immutability (Yadav et al. 2023) and its capacity to execute self-enforcing smart contracts (John et al. 2023) are what make disintermediated issuance, transfer, and settlement technically feasible in the first place. On this basis, the appeal of tokenization is usually framed around three promises: broader access and liquidity through fractional ownership, procedural efficiency through disintermediation, and traceability through on-chain recording (Benedetti & Rodriguez-Garnica, 2023; Swinkels, 2023; Tanveer et al. 2025). Yet the same literature is consistent in that these promises are contingent on conditions that lie well beyond the ledger: the enforceability of the token–asset legal bond, compliance and identity architecture, smart contract and key-management security, off-chain data integrity, and the readiness of secondary-market infrastructure (Bayan et al. 2025; Lavayssière, 2025; Zhao et al. 2025). Tokenization is therefore best treated not as a technical artifact but as a systemic innovation whose success depends on the alignment of technological, organizational, and environmental conditions.

Among these conditions, regulatory certainty occupies a distinctive place. A tokenized claim carries value only when the right it encodes is legally enforceable; without a firm legal bond, a token degrades into a "digital twin" of limited standing, weakening transferability and market acceptance (Garcia-Teruel & Simón-Moreno, 2021; Lavayssière, 2025). Regulatory clarity likewise conditions institutional participation by containing compliance and reputational risk (Daly, 2023; Jūrmalis et al. 2025). This salience is sharpened in Indonesia, where the enabling environment remains transitional: the supervision of digital financial assets has shifted to the financial-sector regulator, and staged governance through a regulatory sandbox has been established while a comprehensive tokenization framework is still being formulated after several business models graduated from that sandbox (Kontan, 2025; OJK, 2024a, 2024b). Implementation has thus preceded comprehensive regulation, which makes the relative priority among factors a question of direct policy consequence rather than an abstract one. What the conceptual literature does not settle is whether regulatory certainty actually drives the other conditions or merely accompanies them.

Capturing this cross-dimensional character requires a framework built for ecosystem-level complexity rather than individual choice. The Technology–Organization–Environment (TOE) framework serves this role: it situates the implementation of an innovation in three simultaneous contexts, technological characteristics and readiness, organizational capability and governance, and an external environment of regulation, market conditions, and infrastructural support (Bhat et al. 2025; Dehghani et al. 2022). This breadth distinguishes TOE from individual-level adoption models such as the Technology Acceptance Model or Diffusion of Innovation, which foreground user perception or the spread of an innovation and are ill-suited to a multi-actor phenomenon whose outcome turns on regulation, market infrastructure, and organizational readiness. In this framework, TOE functions as an interpretive lens rather than a predictive model: it advances no hypotheses about the magnitude of particular effects but supplies a dimensional structure that keeps the set

of implementation factors balanced across technical, organizational, and environmental concerns and that guides how their relationships are read (Rahman et al. 2024; Teng et al. 2025). Consistent with this use, a set of candidate implementation factors was derived from the tokenization and blockchain adoption literature and grouped deductively under the three TOE dimensions, forming the factor scaffold the study examines.

A recurring limitation cuts across this literature. The determinants of tokenization and blockchain adoption have been identified in growing detail, such that a systematic review of 880 adoption factors organized under TOE could still single out the interdependence and multidimensionality of those factors as the direction that remains unaddressed (Zhang et al. 2024). Factor inventories specific to asset tokenization have since been assembled (Misztal, 2026), yet they present determinants as parallel lists or benefit–cost accounts rather than as an interdependent structure. The field increasingly knows which factors matter while leaving open how they relate: which factor drives others, which is merely a dependent outcome, and in what order intervention should proceed. This shift from identifying factors to structuring their relationships is what the present study is positioned to address.

Recent work approaches have targeted three axes without reaching them. Contextually, RWA tokenization in Indonesia is no longer unexamined: gold-backed tokenization and the GORO property platform have been documented in legal-descriptive, single-case academic treatments (Oudang et al. 2026; Utomo et al. 2025); early digital bond instruments such as IDDB have likewise entered practice, although so far only through industry reporting rather than peer-reviewed study (Nanovest, 2024). None of these sources model how implementation factors interrelate. Methodologically, expert-based prioritization of tokenization factors already exists, but it has relied on pairwise weighting through the analytic hierarchy process applied to security token offerings (Lee et al. 2025). This approach ranks factors by weight rather than mapping their structural interdependence and on a scope narrower than an RWA-enabling ecosystem. Interpretive structural modeling paired with MICMAC is itself a mature, cross-sector instrument for adoption and implementation problems (Gupta & Sahu, 2023; Meraj et al. 2025), and it has already modeled Indonesian digital finance in the form of the WealthTech ecosystem (Siregar et al. 2025); its contribution here is therefore domain-specific rather than methodological, since WealthTech is not RWA tokenization. On the integration axis, cross-dimensional structuring of RWA has been attempted as design taxonomy (Vella et al. 2026, a preprint) and as architectural systematization (Luo et al. 2026), but these organize system-design attributes and lifecycle layers rather than an expert-elicited causal hierarchy of implementation factors ordered by driving and dependence power.

These strands converge on a single intersection, the identified literature leaves unoccupied: an expert-elicited structural model of the factors that enable RWA tokenization, situated in a setting where comprehensive regulation is still forming. The present framework meets it by pairing TOE with interpretive structural modeling and MICMAC as an analytical approach, TOE supplying balanced coverage across technology, organization, and environment, and the structural-modeling approach supplying what identification-only and taxonomy studies omit: an ordered account of interdependence and of each factor's driving versus dependence power, elicited from expert judgment (Ahmad & Qahmash, 2021; Yadav & Desai, 2017). The framework remains deliberately interpretive; it organizes and reads relationships among existing factors and makes no claim about effect magnitudes. Its contribution is correspondingly bounded (a domain-specific structural account rather than a reconceptualization of TOE), but it is such an account that turns a list of important factors into a basis for sequencing intervention in an ecosystem where practice has run ahead of regulation.

RESULTS

Overview

This section reports the aggregate structural model derived from the four expert elicitations. The analysis proceeded at two levels: a per-expert level that produced four individual matrices and hierarchies, and an aggregate level that combined them into a single model under the majority rule specified in the Method. Only the aggregate model is reported in the main sections as the collective representation of the ecosystem; differences between individual models are summarized separately (Cross-expert divergence, Sensitivity analyses). All matrix values, driving and dependence powers, hierarchy levels, and quadrant

classifications were computed from the four expert SSIMs with a documented script implementing Warfield-type level partitioning, full transitive closure, and MICMAC. An earlier processing of the aggregate SSIM in ExSimpro reported a thirteen-level structure with F14 as the sole Linkage factor; that structure cannot be reproduced by standard full closure from the same aggregate SSIM when F1 and F14 are mutual, which yields three levels (Table 5). The discrepancy is disclosed here, and the figures reported in this article are those of the documented script. ISM reports the ordinal position of each factor in a directed hierarchy, and MICMAC reports each factor's driving power and dependence power; neither reports the magnitude or statistical significance of any relation.

Strategic Factors and Expert Panel

Fifteen strategic factors (F1–F15) entered the model. Under the TOE framework they distribute as five Technology factors (F5–F9), five Organization factors (F3, F10, F13, F14, F15), and five Environment factors (F1, F2, F4, F11, F12), an even distribution of five factors per dimension. Custody and safeguarding (F10) is classified as Organization because it concerns the institutional arrangements of custodians and safekeeping responsibilities; the dimension-level comparison in the Discussion also reports how the means change if F10 were classified as Environment. Table 2 lists each factor with its TOE dimension and operational definition. The panel comprised four experts selected to represent the key actor nodes of the ecosystem (a regulator, an industry operator, an IT practitioner, and a blockchain academic), whose profiles, expertise, and interview details appear in Table 1 (Method). In-depth interviews were conducted in March 2026. Each expert's completed matrix was returned for validation: two experts approved without change, and two returned documented symbol corrections that were reconciled with the hierarchy each expert had approved.

Structural Self-Interaction Matrix and Aggregation

Each expert produced a Structural Self-Interaction Matrix (SSIM) recording the direct relationship for every pair of factors across the 105 pairs of the upper triangle, using the symbols V, A, X, and O. The number of active relations (V + A + X) varied across experts, from 55 active pairs (52.4 percent) for N4 to 78 active pairs (74.3 percent) for N1; the aggregate SSIM density was 61.0 percent, which lies within the individual range. A-symbols were almost entirely absent: N1 recorded one, on the F12–F14 pair, and N4 recorded one, on the F1–F5 pair (coding smart-contract quality assurance as an influence on regulatory clarity); the other two experts recorded none. Across the panel, V accounted for 60.7 percent of judgments against 0.5 percent for A, a ratio above 120 to 1. Because pairs were presented in ascending factor order, and the factor numbering runs broadly from regulatory foundations to market adoption, this asymmetry may partly reflect presentation order rather than judgment alone; the limitation is stated here and revisited in the Discussion. Mutual (X) relations were rare but consequential: F5↔F6 (smart-contract quality assurance and cybersecurity) and F4↔F6 (privacy and cybersecurity) appeared in all four SSIMs, and F1↔F14 (regulatory clarity and stakeholder coordination) in three of four, the pair whose resolution is described in the Method.

The aggregate SSIM was formed pair by pair under a majority rule of at least three of the four experts. Ninety-two of the 105 pairs (87.6 percent) reached this majority; three of them were set against it on substantive grounds, so 89 pairs (84.8 percent) stand as majority-coded. Thirteen pairs split two to two and were resolved by the domain-expertise priority rule. Counting the F1–F14 decision described in the Method, seventeen pairs (16.2 percent) therefore rest on research-team decisions, listed in Appendix A. Unanimity across all four experts was reached on 61 of 105 pairs (58.1 percent), with Fleiss' kappa = 0.539. The aggregate model rests on moderate, majority-level consensus rather than on unanimity. The sensitivity analyses show that the sixteen exceptions other than F1–F14 leave the ten-level hierarchy unchanged, whereas the F1–F14 decision does not.

Reachability Matrices

Each SSIM was converted into an Initial Reachability Matrix (IRM), a binary 15×15 matrix, and then into a Final Reachability Matrix (FRM) through full transitive closure. In the FRM the driving power (DP) of a factor is the size of its reachability set and the dependence power (Dep) is the size of its antecedent set. Transitivity raised several driving powers relative to the direct matrix: in the aggregate, F1 reached a driving power of 15, meaning it reaches every other factor once indirect paths are counted, although its direct out-degree was 10. Across the aggregate FRM, driving power ranged from 15 (F1) down to 1 (F15), and dependence power from 1

(F1) up to 15 (F15); the row and column sums each total 118, and the matrix satisfies the consistency conditions implied by transitivity, no factor's dependence exceeds the number of factors whose driving power is at least as large, and driving power declines monotonically along every directed path. These aggregate DP and Dep values anchor both the ISM hierarchy and the MICMAC classification reported below.

ISM Hierarchy

Level partitioning of the aggregate FRM produced a hierarchy of ten levels, presented in Figure 2. F1 (regulatory clarity and licensing) occupied the base as the single ROOT at Level 10, carrying the maximum driving power of 15 and the minimum dependence of 1, the model's only pure driver. F15 (user adoption, trust and literacy) occupied Level 1 alone as the single terminal factor, with driving power 1 and dependence 15. One genuinely mutual set appeared: F4, F5, and F6 (privacy and data protection, smart-contract quality assurance, and cybersecurity and key management) are mutually reachable and therefore share Level 7, each with driving power 12. Four further levels contain two factors that resolve at the same partitioning step without being mutually reachable: F7 and F9 at Level 5, F11 and F13 at Level 3, and F12 and F14 at Level 2. F14 (stakeholder coordination), positioned mid-structure in earlier accounts of this dataset, resolves at Level 2 with driving power 2, the penultimate level, immediately below user adoption.

The fifteen factors group into four functional bands across the ten levels: a root band (F1); a foundation band immediately above it (F2, F3, and the mutual triad F4, F5, F6); a transmission band carrying influence outward from the foundations (F8, F7, F9, F10); and a maturation band in which market and adoption outcomes settle (F11, F13, F12, F14, F15). The bands describe position in the hierarchy and should not be read as MICMAC quadrant labels (the band label "transmission" is used to avoid confusion with the MICMAC Linkage quadrant); the two classifications are reported separately and, as shown below, the aggregate model contains no factor in the MICMAC Linkage quadrant.

Figure 2, Aggregate ISM hierarchy of the fifteen strategic factors. Note. Read from the base (Level 10) upward. Each arrow connects a factor to a factor it directly influences in the closed matrix, after arcs implied by transitivity are removed (a Hasse diagram of the final reachability matrix); every arrow ends on the box of the influenced factor. The dashed enclosure marks the mutually reachable set F4, F5, and F6 (double-headed arrows). Factors sharing Levels 5, 3, and 2 resolve at the same partitioning step but are not mutually reachable. DP and Dep are driving and dependence power from the aggregate FRM under the F1–F14 convention. Bands describe position in the hierarchy and are not MICMAC quadrants.

MICMAC Classification

The MICMAC analysis classified each factor by its aggregate driving and dependence power relative to a midpoint of 7.5 on the 0–15 scale, into four quadrants: Independent/driver (DP at least 7.5, Dep below 7.5), Linkage (DP at least 7.5, Dep at least 7.5), Dependent (DP below 7.5, Dep at least 7.5), and Autonomous (both below 7.5). Table 3 reports the aggregate coordinates and quadrant of every factor.

Seven factors fell in Quadrant I (drivers): F1, F2, F3, F4, F5, F6, and F8. F1 was the most extreme driver on both axes (DP 15, Dep 1) and the model's only pure driver; F2 (14, 2) and F3 (13, 3) followed; the mutual triad F4, F5, and F6 shared identical coordinates (12, 6); and F8 (8, 7) sat just above the driving-power midpoint. Seven factors fell in Quadrant III (dependent): F9 (7, 8), F10 (6, 10), F11 (4, 11), F13 (3, 11), F12 (2, 12), F14 (2, 13), and F15 (1, 15), with F15 at the extreme corner. One factor, F7 (7, 7), fell in Quadrant IV (autonomous), sitting just below the midpoint on both axes. Quadrant II (Linkage) was empty at the 7.5 midpoint. This statement is conditional. It depends on the midpoint (at 7, F7, F8, and F9 enter Quadrant II, and at 6 so do F4, F5, F6, and F10) and on the F1–F14 convention (if the mutual coding is retained, thirteen factors are Linkage). The empty quadrant is therefore reported as a property of the analyst-resolved model at the conventional midpoint (Figure 3), not as an established property of the ecosystem.

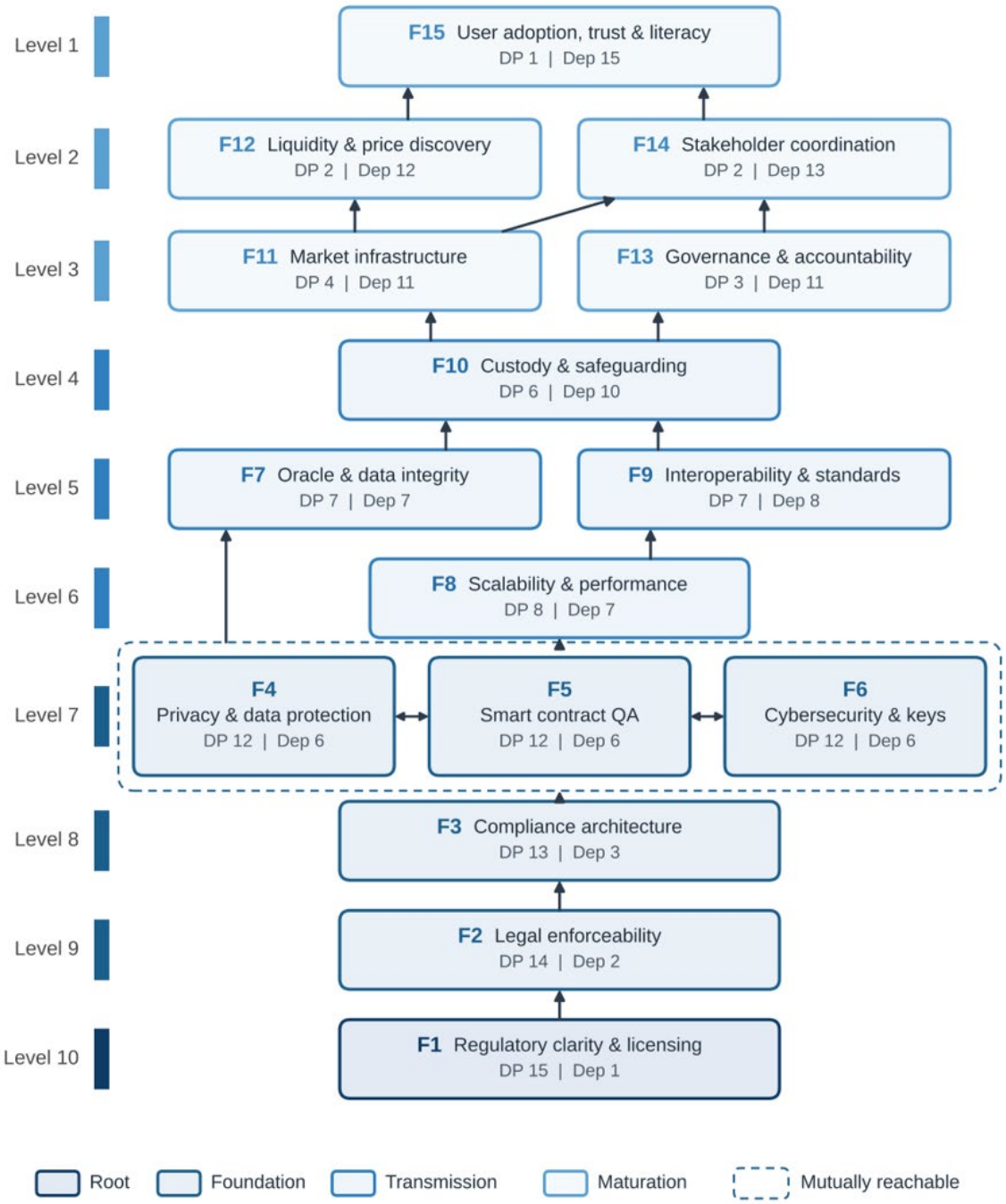

Figure 2. Aggregate ISM hierarchy of the fifteen strategic factors. Note. Read from the base (Level 10) upward. Each arrow connects a factor to a factor it directly influences in the closed matrix, after arcs implied by transitivity are removed (a Hasse diagram of the final reachability matrix); every arrow ends on the box of the influenced factor. The dashed enclosure marks the mutually reachable set F4, F5, and F6 (double-headed arrows). Factors sharing Levels 5, 3, and 2 resolve at the same partitioning step but are not mutually reachable. DP and Dep are driving and dependence power from the aggregate FRM under the F1–F14 convention (Appendix B). Bands describe position in the hierarchy and are not MICMAC quadrants.

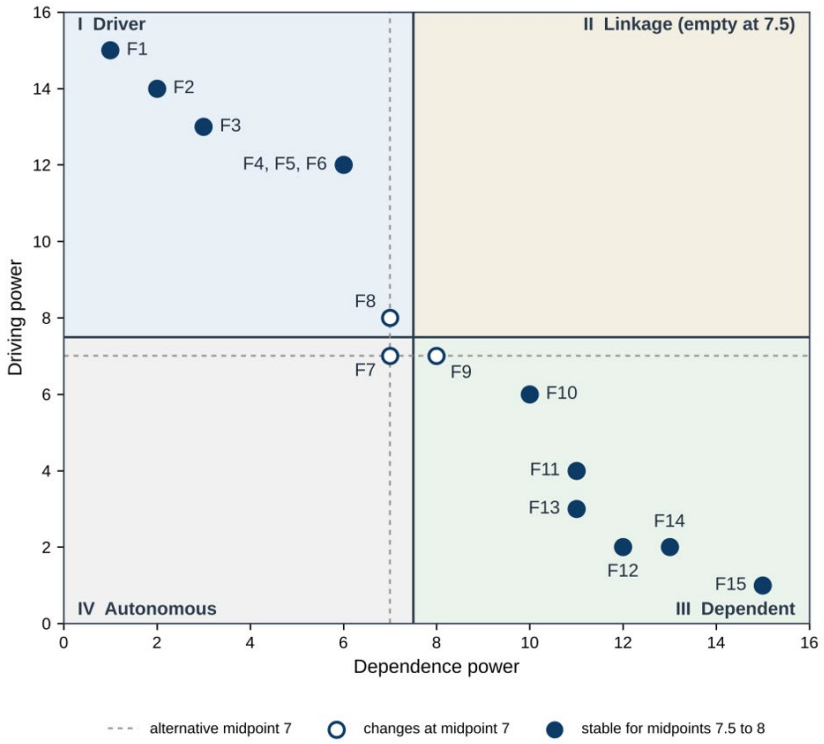

Figure 3. MICMAC map of the aggregate model (driving power against dependence power). The solid lines mark the adopted midpoint (7.5) and the dotted lines the alternative midpoint 7. Open markers (F7, F8, F9) change quadrant at a midpoint of 7; F4, F5, and F6 share the coordinates (dependence 6, driving 12). Quadrant II (Linkage) is empty at 7.5 and contains F7, F8, and F9 at 7.

Three factors sit within one unit of the midpoint and their classification is not robust to its choice. F7 (oracle and data integrity) is Autonomous at (7, 7), F8 (scalability and performance) is a driver at (8, 7), and F9 (interoperability and standards) is Dependent at (7, 8). Adopting a midpoint of 7 rather than 7.5 moves all three into the Linkage quadrant (F7 at (7, 7), F8 at (8, 7), F9 at (7, 8)); the median of the observed driving-power distribution is also 7 and gives the same result. The mean driving power (7.87) gives the same classification as 7.5. At midpoints of 8.5 and 9, F8 and F9 move to Autonomous. The Linkage quadrant is empty only for midpoints from 7.5 to 9. We report 7.5 because it is the conventional midpoint in the ISM–MICMAC literature applied here (Yadav & Desai, 2017), but the classification of F7, F8, and F9 should be treated as provisional, and the statement that no factor is a Linkage factor is tied to the 7.5 midpoint and to the F1–F14 convention. The positions of F1 as the sole pure driver and F15 as the sole terminal dependent factor are unaffected by any midpoint between 6 and 9 within this model.

Cross-expert divergence

Table 4 summarizes the individual models on four structural positions: the ISM root, the Level-1 terminal factor, the MICMAC quadrant of F14, and the number of hierarchical levels. Each model was recomputed from that expert's own SSIM with the F1–F14 convention applied to all four, which departs from the coding of N2, N3, and N4 (Method). Under this shared convention, regulatory clarity (F1) is the sole root in the models of N1, N2, and N3, and one of six co-equal roots in N4's model, where F1 to F6 are mutually reachable at the base; F1 carries driving power 15 in all four. User adoption (F15) is the sole Level-1 terminal factor in all four models. Stakeholder coordination (F14) falls in the Dependent quadrant in all four, with driving power 2 to 4 and dependence 13 to 14, and no individual model places a factor in the Linkage quadrant.

Two cautions apply. First, these agreements are produced partly by the shared convention. With each expert's own F1–F14 coding, only N1's model yields a ten-level hierarchy; the models of N2, N3, and N4 collapse into a three-level structure in which F14 is

a Linkage factor (Table 5). The agreement in Table 4 is therefore agreement on the structural extremes (root and terminal factor), not evidence that three of four experts regard F14 as dependent. Second, the divergence concerning the root is narrower than a majority-rule reading suggests. N4 codes the F1–F5 relation in the opposite direction to the others (the only A-symbol besides N1's F12–F14) and, under the shared convention, shares a six-factor base with F1. N4 therefore treats technological and regulatory foundations as jointly foundational, a claim about the granularity of the foundation layer; it is compatible with the aggregate structure rather than opposed to it.

Sensitivity analyses

Table 5 reports the scenarios described in the Method. Three results stand out. First, the sixteen exceptions other than F1–F14 do not matter for the hierarchy: coding ties as unrelated, following N1, following N1 only when N2 agrees, or removing the three majority overrides all reproduce the same ten-level structure, root, terminal factor, and quadrant of F14. Second, the F1–F14 relation does matter. Coding it X or A collapses thirteen factors into one cycle (three levels, F14 as Linkage with the same coordinates as twelve other factors); coding it O or V yields an identical ten-level hierarchy. Third, the individual and leave-one-out checks are conditional on that convention. With each expert's own F1–F14 code, N2, N3, and N4 collapse as the aggregate does; because three of four experts coded the pair X, every leave-one-out aggregate also pools it as X, and collapses unless the convention is applied. With the convention applied, leave-one-out aggregates yield nine or ten levels, with F1 as the root, F15 as the terminal factor, F14 as Dependent (2, 13), F7 as Autonomous, and no Linkage factor at 7.5.

Table 3. Aggregate MICMAC classification of the fifteen strategic factors

Code	Factor	DP	Dep	Quadrant
F1	Regulatory clarity & licensing	15	1	I, Independent (driver)
F2	Legal enforceability	14	2	I, Independent (driver)
F3	Compliance architecture (KYC/AML)	13	3	I, Independent (driver)
F4	Privacy & data protection	12	6	I, Independent (driver)
F5	Smart contract quality assurance	12	6	I, Independent (driver)
F6	Cybersecurity & key management	12	6	I, Independent (driver)
F8	Scalability & performance	8	7	I, Independent (driver)
F7	Oracle & data integrity	7	7	IV, Autonomous
F9	Interoperability & standards	7	8	III, Dependent
F10	Custody & safeguarding model	6	10	III, Dependent
F11	Market infrastructure readiness	4	11	III, Dependent
F13	Governance & accountability design	3	11	III, Dependent
F12	Liquidity & price discovery	2	12	III, Dependent
F14	Stakeholder coordination	2	13	III, Dependent
F15	User adoption, trust & literacy	1	15	III, Dependent

Table 4. Cross-expert divergence on ROOT, top level-1 position, and the position of F14 (F1–F14 convention applied to all models)

Model (role, TOE dimension)	Levels	ISM root	Level-1 terminal	F14 (DP, Dep, quadrant)
N1, regulator (Environment)	10	F1	F15	4, 14, III Dependent
N2, industry issuer (Organization)	10	F1	F15	2, 13, III Dependent
N3, IT practitioner (Technology)	10	F1	F15	2, 13, III Dependent
N4, academic technologist (Technology)	6	F1, F2, F3, F4, F5, F6 (co-roots)	F15	2, 13, III Dependent
Aggregate	10	F1	F15	2, 13, III Dependent

Table 5. Scenario comparison for the F1–F14 relation, aggregation rules, individual experts, and leave-one-out aggregates (MICMAC midpoint 7.5)

Scenario	Levels	Base (root)	Top	F14 (DP, Dep, quadrant)	Linkage at 7.5
Aggregate, F1 influences F14 (adopted convention)	10	F1	F15	2, 13, Dependent	None
Aggregate, F1–F14 coded O	10	F1	F15	2, 13, Dependent	None
Aggregate, F1–F14 mutual (X, majority coding)	3	13 factors (one cycle)	F15	15, 13, Linkage	13 factors
Aggregate, F14 influences F1 (A)	3	13 factors (one cycle)	F15	15, 13, Linkage	13 factors
Ties coded O (convention applied)	10	F1	F15	2, 13, Dependent	None
Ties follow N1 (convention applied)	10	F1	F15	2, 13, Dependent	None
Ties follow N1 only if N2 agrees (convention applied)	10	F1	F15	2, 13, Dependent	None
No overrides of three majority pairs (convention applied)	10	F1	F15	2, 13, Dependent	None
N1 own coding (F1–F14 = V)	10	F1	F15	4, 14, Dependent	None
N2 own coding (F1–F14 = X)	3	13 factors (one cycle)	F15	15, 13, Linkage	13 factors
N3 own coding (F1–F14 = X)	3	13 factors (one cycle)	F15	15, 13, Linkage	13 factors
N4 own coding (F1–F14 = X)	3	13 factors (one cycle)	F15	15, 13, Linkage	13 factors
N1 to N4 with convention applied	10, 10, 10, 6	F1 (N4: F1 to F6)	F15	2 to 4, 13 to 14, Dependent	None
Leave-one-out, F1–F14 pooled as coded (four runs)	3 (all)	13 factors (one cycle)	F15	15, 13, Linkage	13 factors
Leave-one-out, convention applied (four runs)	9 (omit N1, N3); 10 (omit N2, N4)	F1	F15	2, 13, Dependent	None

Table 6. MICMAC classification of the aggregate model under alternative midpoints (adopted convention for F1–F14)

Midpoint	Driver	Linkage	Dependent	Autonomous
6	F1, F2, F3	F4, F5, F6, F7, F8, F9, F10	F11, F12, F13, F14, F15	None
6.5	F1 to F6	F7, F8, F9	F10 to F15	None
7 (median)	F1 to F6	F7, F8, F9	F10 to F15	None
7.5 (adopted)	F1 to F6, F8	None	F9 to F15	F7
7.87 (mean)	F1 to F6, F8	None	F9 to F15	F7
8	F1 to F6, F8	None	F9 to F15	F7
8.5	F1 to F6	None	F10 to F15	F7, F8, F9
9	F1 to F6	None	F10 to F15	F7, F8, F9

In sum, three positions are stable across every scenario that shares the F1–F14 convention: F1 at the base, F15 at the top, and F14 as a dependent factor. Two statements are conditional and are reported as such throughout: the empty Linkage quadrant (tied to the 7.5 midpoint and to the convention) and the dependent position of F14 (tied to the convention). The structure that the three non-regulator experts' own coding implies is the thirteen-factor cycle in Table 5, and no analysis in this study can distinguish it from a model in which F14 feeds back into regulatory clarity.

Discussion

This study asked how the strategic factors for RWA tokenization in Indonesia are ordered in an expert-elicited structure, not merely which factors matter. Under the analyst-resolved convention for F1–F14, the

integrated ISM–MICMAC model shows a regulation-first ordering across ten levels: regulatory clarity is positioned at the base and is the only pure driver, a mutually reachable set of privacy, smart-contract quality assurance, and cybersecurity occupies the foundation layer, and user adoption is the single terminal factor. At the conventional 7.5 midpoint no factor is classified as Linkage. These statements describe how four experts' judgments, aggregated and closed under transitivity, are structured. They are not estimates of policy effects. The ordering is also conditional on three analytical choices examined in the sensitivity analyses: the F1–F14 convention, the tie-resolution rules, and the MICMAC midpoint. The remainder of this section interprets the ordering, separates what is stable from what is conditional, compares it with prior work, and states its boundaries.

ISM specifies the direction of elicited influence between factors (which factor the experts position as enabling which), and MICMAC specifies how far a factor's influence reaches in the closed matrix. Read together they yield a provisional sequencing heuristic, not a verified implementation order. Regulatory clarity has the highest driving power because the experts coded it as influencing nearly every other factor, directly or through intermediaries; user adoption has the lowest because the experts coded it as influencing none. This is consistent with the view that literacy and inclusion measures aimed directly at adoption are unlikely to be sufficient while antecedent conditions remain unsettled, and with giving early attention to regulatory clarity and legal enforceability ahead of downstream custody, market infrastructure, and liquidity. It does not show that downstream factors are unimportant, or that effort committed to them returns little before the foundations are consolidated: the model contains no information on effect sizes, costs, or returns. The resulting sequence should be read as a set of provisional priorities for regulators and industry to test, conditional on the coding and midpoint assumptions reported here.

The most consequential analytical choice concerns stakeholder coordination (F14). Three of four experts coded F1 and F14 as mutually influencing. Retaining that coding collapses the structure into a thirteen-factor cycle; the hierarchy reported here exists only because F14 is treated as not influencing F1, which follows the regulator's coding and is an analytical convention rather than a panel majority. Under that convention F14 is a near-pure dependent factor (driving power 2, dependence 13) at Level 2, in the aggregate, in the leave-one-out aggregates, and in the individual models that share the convention. Under the experts' own coding it is instead a Linkage factor whose coordinates are identical to those of twelve other factors. An earlier processing of this dataset reported F14 as the sole Linkage factor, which is consistent with the two-way relation reported by the three non-regulator experts. The two readings are not equally supported by the panel: the non-regulator majority favors a two-way relation, and the dependent reading rests on the regulator's coding together with the need for a hierarchy. We therefore do not conclude that early coordination is ineffective. The defensible statement is narrower: if coordination does not feed back into regulatory clarity, it is positioned downstream of the regulatory, legal, and technical foundations; if it does, these data cannot separate the two. Testing the feedback directly, with a larger panel or a method that tolerates cycles, is the natural next step.

Interpreted through the technology–organization–environment (TOE) lens that frames this study, the result refines the theory rather than overturning it, and the refinement must be stated at the level the evidence supports. TOE treats its three dimensions as jointly necessary for adoption (Dehghani et al. 2022; Teng et al. 2025) yet says little about which dimension leads in a given setting, and the interdependence and relative priority of adoption factors remain expressly open questions in the field (Zhang et al. 2024). This model seats a single Environment-dimension factor, regulatory clarity, at the base of the hierarchy. It does not, however, show that the Environment dimension as a whole drives the system: computed across the aggregate FRM, mean driving power is 9.40 for Environment, 9.20 for Technology, and 5.00 for Organization. The Environment mean exceeds the Technology mean by only 0.20 points and averages three strong drivers (F1, F2, F4) with two dependent factors (F11, F12), so it describes no common position; moving custody (F10) from Organization to Environment would instead give 9.20 for Technology, 8.83 for Environment, and 4.75 for Organization. The dimension ranking therefore depends on a single classification choice and is not interpreted. The defensible claim is therefore a factor-level one, that regulatory clarity is the root in a pre-regulatory emerging-market ecosystem, not a dimension-level claim that Environment leads. This distinction matters because the dimension-level version would be the more interesting theoretical statement, and the data do not

support it. The result still runs against the technology-centered emphasis common in blockchain-adoption work, exemplified by Lee et al.'s (2025) AHP-based prioritization of security-token success factors, in which blockchain-security technology ranks as most critical. The divergence is explicable: AHP elicits each factor's isolated importance weight, so a factor may rank highest in salience without being positioned as the origin of influence, whereas ISM maps the elicited direction of influence and can therefore seat a lower-weighted factor at the base; their security-token setting also sits in a more settled regulatory environment than Indonesia's pre-regulatory sandbox. Consistency with Lavayssière (2025), for whom regulatory uncertainty is the chief barrier to tokenization in emerging markets, and with Misztal's (2026) mapping of tokenization-adoption factors that nonetheless stops short of a causal hierarchy, casts this study's contribution as supplying the ordering such accounts leave unspecified.

The empty Linkage quadrant must be read with the same conditions. It holds at midpoints from 7.5 to 9 and at the mean-based midpoint (7.87), but not at 7 or below, where F7, F8, and F9 become Linkage factors (and more factors at 6), and it does not hold when the mutual F1–F14 coding is retained. In Godet's (1994) reading, Linkage variables are inherently unstable, so a structure with none would offer a more tractable policy landscape. Whether the empty quadrant is a feature of the ecosystem or of the convention and midpoint chosen cannot be settled here. One conjecture is that, in an ecosystem still awaiting its regulatory framework, feedback from market development to upstream rules has had little time or scale to form; this is a hypothesis for follow-up work, which could test whether the quadrant fills as the framework matures. That ISM–MICMAC suits Indonesian digital-finance ecosystems is not itself novel: Siregar et al. (2025) apply the same pairing to the country's WealthTech ecosystem, but WealthTech is an adjacent domain, and the structure reported here is specific to RWA tokenization.

It is important to state the theoretical claim at its true weight and no higher. This study introduces no new construct, no reconceptualization of TOE, and no novel mechanism; the ISM–MICMAC pairing is itself well established across adoption domains, and its novelty here is confined to the RWA application. What the study contributes is a factor-level boundary-condition refinement: it specifies that in a pre-regulatory emerging-market ecosystem, where market implementation has outrun its regulatory framework, regulatory clarity occupies the root driving position while the Environment dimension, which combines drivers with dependent factors, does not lead as a unit. That is a modest, context-bound sharpening of an existing theory's scope, offered as an empirical-methodological result with limited conceptual reach and grounded in a single panel and a single setting, not as a general claim that regulation leads everywhere. The study's second contribution is procedural rather than theoretical: by publishing the four expert matrices, both reachability matrices, and the partitioning iterations, it makes an expert-elicited structural model auditable in a literature where such models are ordinarily reported only as summary coordinates.

Because the evidence is structural-qualitative rather than statistical, its reach is a matter of transferability, not statistical generalization. The regulation-first cascade is most likely to recur in other pre-regulatory emerging markets that share this case's defining condition (market implementation preceding a comprehensive regulatory framework), where regulatory clarity is correspondingly the binding constraint. Its transfer is bounded in three ways. First, the model reflects the three asset classes that cleared the OJK sandbox (gold, government securities, and property), and other classes, such as agricultural commodities or intellectual property rights, may present a different factor structure. Second, it is a snapshot of a specific moment: with a comprehensive digital-asset framework moving through public consultation in late 2025 (SSEK Legal Consultants, 2025), the very condition that seats regulation at the root is being dismantled, and the structure may migrate toward the technology-first configuration that N4 anticipates as that framework matures. Third, the model should not be applied to mature regulatory jurisdictions (Singapore, Hong Kong, or the United Arab Emirates), where an existing framework would likely shift the binding constraint to technological or market factors.

Five alternative explanations cannot be excluded and temper the claims accordingly. The first is aggregation: with four experts and a majority threshold, 17 of 105 pairs rest on the research team's decisions. The sensitivity analyses show that 16 of them leave the hierarchy unchanged and that the F1–F14 decision does not; they also show that expert-level and leave-one-out checks cannot speak to what a panel drawn from different experts would recover. The second is the

cycle-resolution decision on F1–F14, discussed above: a reader who retains the experts' mutual coding obtains a thirteen-factor cycle with no interpretable hierarchy, which is itself informative about how tightly regulation and coordination are bound in expert judgment. The third is elicitation order: with V outnumbering A by more than 120 to 1 and pairs presented in ascending factor order, the downward flow of influence in the hierarchy may partly reflect the instrument rather than the judgments, and a replication with randomized pair order would address this. The fourth concerns vantage: the panel leans toward regulator- and industry-proximate perspectives, custodian, venue, and investor perspectives are absent, and one member of the research team has a disclosed prior professional association with the regulator informant's unit, whose coding underlies the F1–F14 convention. The fifth is classification: dimension-level means depend on how single factors are assigned to TOE dimensions, and the Environment mean exceeds the Technology mean by only 0.20 points under the classification used here.

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

This study modeled the structural interdependence of 15 strategic factors for real-world asset (RWA) tokenization in Indonesia and found that, under an analyst-resolved convention for the F1–F14 relation, expert judgments order the enabling ecosystem as a regulation-first hierarchy of ten levels: regulatory clarity is positioned at the base and is the only pure driver, a mutually reachable triad of privacy, smart-contract quality, and cybersecurity occupies the foundation layer, and user adoption is the single terminal factor. At the 7.5 midpoint no factor is a Linkage factor, and stakeholder coordination is a dependent factor. Both statements are conditional: the hierarchy does not exist if the experts' mutual F1–F14 coding is retained, and the empty Linkage quadrant does not hold at a midpoint of 7. The theoretical contribution is deliberately modest. It is a factor-level boundary-condition suggestion, that in a pre-regulatory emerging-market ecosystem regulatory clarity occupies the base position, while the Environment dimension, which combines three drivers with two dependent factors, does not lead as a unit; it is not a new construct and not a general law. The ordering corroborates accounts that identify regulatory uncertainty as the chief barrier to tokenization in emerging markets (Lavayssière, 2025) and reviews that treat adoption factors as interdependent (Zhang et al. 2024; Misztal, 2026). It contrasts with the technology-centered ranking in an AHP study of security-token success factors (Lee et al. 2025); that difference reflects method (importance weights versus structural position) and a more settled regulatory setting, and need not indicate disagreement on the evidence.

The practical implications concern provisional sequencing and are conditional on the coding and midpoint assumptions. For regulators, the model suggests treating completion of a comprehensive, cross-asset POJK on RWA tokenization (F1) and legal certainty over the token-asset claim (F2) as the first tier of a sequence to be tested, ahead of downstream market infrastructure, liquidity, and adoption measures. The model does not show that early stakeholder coordination is ineffective; it shows that, if coordination does not feed back into regulatory clarity, it is positioned downstream of regulatory settlement, and the data cannot rule out feedback. For industry players and associations, internal readiness may reasonably begin with the foundation layer, with liquidity and user adoption positioned as outcomes. Indonesia already holds an initial foundation through the OJK regulatory sandbox, which has admitted tokenization models across three asset classes (gold, government bonds, and property); whether the sequence yields better outcomes than parallel strengthening is an empirical question these data do not answer.

Recommendations

Six limitations bound these conclusions. The panel comprised four purposively selected experts, with custodian, venue, and investor perspectives absent; the expert-level and leave-one-out analyses show dependence on no single expert only under the F1–F14 convention, and cannot show what a different panel would produce. Seventeen of 105 pairs were set by the research team, and one of them (F1–F14) determines whether an informative hierarchy exists. The near-absence of A-symbols suggests the elicitation order may have influenced the direction of recorded relations. The MICMAC classification of F7, F8, and F9 and the empty Linkage quadrant depend on the midpoint. The ISM–MICMAC approach is qualitative-structural: it maps the direction of interdependence but does not quantify the strength of relationships, and it supports no causal inference. The scope covers only three asset

classes that have cleared the sandbox, and the findings are time-sensitive, reflecting the regulatory conditions described in the Introduction. Future research could quantify relationship strengths through Structural Equation Modeling, the Analytic Network Process, or DEMATEL; use a method that tolerates cycles to test whether coordination feeds back into regulation; replicate the elicitation with randomized pair order and a larger, more diverse panel; extend the model to additional asset classes; benchmark Indonesia against more mature jurisdictions such as Singapore, Hong Kong, or the United Arab Emirates; and repeat the study longitudinally to test whether the Linkage quadrant fills as the regulatory framework matures.

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CONFLICTS OF INTEREST: One member of the research team has a prior professional association, predating this study, with the institutional unit represented by expert informant N1. The authors disclose this prior association as a potential competing interest. The regulator's coding underlies the F1–F14 convention, which is the pivotal analytical choice; the possible influence of the association on that choice is acknowledged. The association was addressed through an auditable elicitation trail, majority-rule aggregation, and the expert-level and leave-one-out analyses reported in Findings, which examine dependence on any single expert only under the stated convention. In addition, expert informant N4 is affiliated with the same university as the authors; this institutional affiliation is disclosed here, and N4's coding is one of four inputs whose influence is examined in the expert-level and leave-one-out analyses. The identifying details of both relationships are given on the title page and in the confidential cover letter, in line with the journal's double-blind policy.

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