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Smart-Contract-Enabled Diminishing Musharakah in Bangladesh: A Doctrinal-Functional Analysis and Six-Layer Control Architecture

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ABSTRACT

Purpose: Diminishing musharakah, known in Bangladesh as hire purchase under shirkatul melk (HPSM), links home and asset finance to shared ownership and gradual transfer. Its integrity depends on keeping partnership, lease, purchase undertaking and title transfer distinct. This paper asks which parts of the product can safely be executed by smart contracts and which controls are needed to keep an automated version valid under Shariah and Bangladeshi law.

Design/methodology/approach: The study uses doctrinal-functional analysis. It reads the relevant AAOIFI Shari'ah Standards (No. 9 on ijarah and No. 12 on sharikah), IFSB standards, Bangladesh Bank instructions and Bangladeshi statutes against the smart-contract and law-and-technology literature, and classifies each lifecycle function by whether it is deterministic, dependent on off-chain facts, or dependent on judgment.

Findings: Full automation is neither required nor advisable. Ownership-ratio arithmetic, rent and unit-purchase calculation, notices and evidence logging suit automation. Unit pricing policy, asset condition, title, arrears, destruction, hardship and dispute resolution require authorized human decisions. The paper proposes a six-layer architecture (legal prose, Shariah parameter registry, executable code, oracle and evidence service, governance, and remedy) and a ten-state transaction model with guarded transitions.

Originality/value: The paper connects specific Shariah standard clauses to code-level controls and to Bangladesh's registration, electronic-records and Shariah-governance rules, a link missing from existing Islamic FinTech reviews.

Implications: Shariah boards should audit deployed code and event logs, not only product manuals, and regulators should require parallel running and pause-and-correct capability before approving automated HPSM.

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1. INTRODUCTION

Diminishing musharakah (musharakah mutanaqisah) combines co-ownership with a process through which one partner gradually acquires the other's share. In home or asset finance the customer and the financier buy the asset jointly, the customer leases and uses the financier's share against rent, and periodic unit purchases reduce that share until title passes entirely to the customer. Researchers have long presented the structure as closer to Shariah objectives than sale-based alternatives because the financier's return is tied to ownership of a real asset (Meera & Abdul Razak, 2005; Smolo & Hassan, 2011). Later work has modeled its welfare effects and proposed refinements, including ijarah-based variants and "enhanced" forms intended to reduce house-price pressure (Asadov & Ibrahim, 2018; Selim, 2020).

In Bangladesh the same structure appears in bank documentation as hire purchase under shirkatul melk (HPSM). Bangladesh Bank's Guidelines for Conducting Islamic Banking describe it as a mode under which the bank and the client jointly purchase vehicles, machinery, buildings or apartments, with the bank's ownership diminishing as the client pays installments (Bangladesh Bank, 2009). The product is therefore not exotic for Bangladeshi Islamic banks. What is new is the prospect of administering it through smart contracts: programs that execute specified actions when coded conditions are met (Szabo, 1997; Zheng et al., 2020).

The attraction is clear. A diminishing musharakah runs for many years and generates a long sequence of small, rule-based events: rent periods, unit purchases, ownership-ratio updates, statements and notices. These events are tedious to administer by hand and easy to get wrong. A program can calculate them consistently and log each one. The danger is equally clear. A program applies whatever rule it is given. If the rule fuses lease and sale, fixes the unit price at face value, or imposes maintenance on the customer, the program will repeat that defect in every contract it touches. Code also cannot see a flooded apartment, assess a customer's hardship or read a land register (Levy, 2017; Mik, 2017).

Islamic FinTech reviews have identified Shariah compliance and regulatory fit as the main obstacles to adoption (Hasan et al., 2020; Rabbani et al., 2020), and recent jurisprudential work treats smart contracts as acceptable in principle while noting that coding, execution and consensus mechanisms still need scholarly attention (Zulkepli et al., 2026). These studies operate at the level of technology in general. None, to the authors' knowledge, works through a single product clause by clause, maps each Shariah requirement to a code-level control, and tests the result against the registration, electronic-records and governance rules of a specific jurisdiction. That is the gap this paper addresses.

The paper asks three research questions:

- **RQ1.** Which functions in the diminishing musharakah lifecycle can be executed by smart contracts without compromising the validity requirements set by AAOIFI Shari'ah Standards No. 9 and No. 12?
- **RQ2.** Which functions depend on off-chain facts or discretionary judgment and therefore require human authority, and what evidence should that authority produce?
- **RQ3.** What control architecture would allow a Bangladeshi institution to deploy an automated HPSM product consistently with Bangladesh Bank's instructions and the country's contract, registration and electronic-records law?

The paper makes four contributions. First, it decomposes the product into lifecycle functions and classifies each by automation suitability. Second, it maps specific AAOIFI clauses to concrete code and governance controls. Third, it specifies a ten-state transaction model in which every transition names its trigger, required evidence, authorized actor and reversibility. Fourth, it proposes a six-layer control architecture and a staged implementation path for Bangladesh. The analysis is a control model. It is not a fatwa, a legal opinion or a regulatory approval.

The remainder of the paper is organized as follows. Section 2 sets out the doctrinal and theoretical background. Section 3 describes the method. Section 4 presents the functional decomposition and the clause-to-control mapping. Section 5 presents the state model and the six-layer architecture. Sections 6 to 9 discuss the findings, implications, limitations and conclusions.

2. LITERATURE REVIEW AND THEORETICAL BACKGROUND

2.1 Diminishing musharakah in doctrine and practice

AAOIFI Shari'ah Standard No. 12 defines diminishing musharakah as a partnership in which one partner promises to buy the other's equity share gradually until title is completely transferred (Accounting and Auditing Organization for Islamic Financial Institutions [AAOIFI], 2015, SS 12, cl. 5/1). The standard applies the general rules of sharikat al-'inan to the arrangement (cl. 5/2). It requires each partner to contribute capital (cl. 5/4) and the profit or income ratio to be clearly determined (cl. 5/5). Three provisions matter most for automation. The promise to buy, and the sale itself, must be independent of the partnership contract and must not be stipulated in it (cl. 5/1). One partner may give a binding promise to acquire the other's share gradually "according to the market value or a price agreed at the time of acquisition" (cl. 5/7), while the general rules prohibit a promise to buy the partnership assets at face value (cl. 3/1/6/2) and any stipulation that one partner guarantees another's capital (cl. 3/1/4/1). Finally, either partner may lease the other's share for a specified amount and duration (cl. 5/9), and it is not permitted to stipulate that one partner bears all insurance or maintenance costs because he will eventually own the asset (cl. 5/3).

The lease component is governed by Shari'ah Standard No. 9. The lessor may not stipulate that the lessee undertakes major maintenance (AAOIFI, 2015, SS 9, cl. 5/1/7), and permissible insurance is a lessor expense (cl. 5/1/8). Rental must be specified, either for the whole term or by installments, and where a variable rental is used the first period's rental must be specified (cl. 5/2/1, 5/2/3). Total destruction of an identified leased asset terminates the ijarah, and the remaining installments may not be stipulated as payable (cl. 7/1/3). A lessee who delays payment without excuse may undertake to donate an amount to charity under the supervision of the Shari'ah board (cl. 6/4). Where title is to pass to the lessee, the method of transfer must be evidenced in a document separate from the ijarah contract (cl. 8/1).

These clauses are not formalities. Each one allocates risk. The lessor's duty to maintain and insure, the termination rule on destruction and the ban on capital guarantees together keep the financier exposed to ownership risk, which is what distinguishes the structure from a secured loan. El-Gamal (2006) argued that much of Islamic finance replicates conventional products through legal form while the economic substance stays the same. Diminishing musharakah is vulnerable to that critique when documentation turns the purchase undertaking into a guaranteed repayment schedule regardless of what happens to the asset. The literature on home financing confirms both the promise and the risk. Meera and Abdul Razak (2005) compared musharakah mutanaqisah with bay' bithaman ajil and argued for its fairness advantages. Smolo and Hassan (2011) described it as more consistent with Shariah teachings than murabahah-based housing finance. Selim (2020) proposed an ijarah-based diminishing musharakah model designed to remove foreclosure risk, and Asadov and Ibrahim (2018) modeled an enhanced form that, in theory, dampens house-price cycles. The value-based case for risk-sharing over debt has also been restated in recent work tracing Islamic finance from riba avoidance toward risk-sharing and regenerative goals (Zahid et al., 2025).

2.2 Smart contracts, code and law

Szabo (1997) introduced the smart contract as a way of embedding contractual terms in hardware and software so that breach becomes costly or impossible. Current platforms implement the idea as programs stored on a distributed ledger that run when conditions are met (Zheng et al., 2020). Zheng et al. (2020) group the resulting challenges across the creation, deployment, execution and completion of a contract and stress that deployed code is hard to modify. Security research shows the cost of that rigidity: Atzei et al. (2017) catalogued attacks on Ethereum smart contracts that exploited gaps between what programmers intended and what the code actually did.

Legal scholarship draws a sharper line. Werbach and Cornell (2017) accept that smart contracts can form contracts but argue that contract law does more than enforce promises: it supplies remedies, excuses and interpretation after things go wrong, and these functions cannot be fully replaced by automatic performance. Levy (2017) observes that real contracts work partly because parties tolerate ambiguity and choose not to enforce every term; smart contracts are "book-smart" but not "street-smart." Mik (2017) shows that the technical vocabulary of self-executing agreements overstates what code can achieve in commercial settings. Governatori et al. (2018) distinguish imperative smart contracts, which encode procedures, from declarative representations of legal norms, and argue that the legal contract and the executable code must be linked but cannot be treated as identical.

Two further ideas shape this paper's lens. Lessig (2006) argued that code regulates behavior alongside law, norms and markets, so the design of software is itself a form of rule-making. De Filippi and Wright (2018) extend this to blockchain systems, describing a "lex cryptographia" of rules enforced by protocol, and warn that such rules can escape the safeguards of ordinary law. Werbach (2018) adds that blockchain does not remove the need for trust but relocates it, and that legal institutions remain necessary to correct failures. A smart-contract version of diminishing musharakah is therefore a rule-making exercise: whoever writes the code writes, in practice, part of the product's Shariah ruling.

2.3 The oracle problem

A smart contract only knows what is written to the ledger. Payments, title registrations, valuations and physical damage happen elsewhere and must be reported by an oracle, meaning a data feed, device or authorized person. Caldarelli (2020) shows that the oracle reintroduces the trusted intermediary that blockchain was meant to remove and concludes that "the more trusted a system is, the less the oracle problem impacts." For a bank-run, permissioned diminishing musharakah, the implication is practical. The question is not whether to trust anyone but whom to trust for which fact, with what evidence and what fallback.

2.4 Islamic FinTech and Shariah governance

Reviews of Islamic FinTech consistently place Shariah compliance and regulation at the top of the obstacle list (Hasan et al., 2020; Rabbani et al., 2020). Alam et al. (2019) document the spread of digital channels, blockchain and crowdfunding across the industry. Applied work on smart sukuk finds that blockchain can lower costs and widen investor access while leaving underlying Shariah questions, such as capital guarantees, unresolved (Hamza, 2020). Zulkepli et al. (2026) conclude that smart contracts are broadly consistent with Islamic contract theory but that technical dimensions of coding, execution and consensus require further juristic work. In Bangladesh, Shariah-compliant mobile-banking services have been examined through a jurisprudential lens that evaluates digital financial services against Islamic contract rules (Haque & Zahid, 2026). Work on artificial intelligence in fatwa and Shariah advisory reaches a parallel conclusion: automated tools can assist with retrieval and preliminary analysis, but final juristic judgment must stay with qualified humans (Billah & Zahid, 2026).

Shariah governance standards supply the institutional side. IFSB-10 describes a Shariah governance system with ex-ante components (pronouncements and their dissemination) and ex-post components (internal Shariah compliance review and an annual review), the internal review being the step at which non-compliance is recorded, reported and as far as possible rectified (Islamic Financial Services Board [IFSB], 2009). IFSB-1 treats Shariah non-compliance as part of operational risk and requires musharakah exposures to be managed as equity investment risk with defined exit strategies approved by the Shariah board (IFSB, 2005). IFSB-

30 revises corporate governance principles for Islamic banks (IFSB, 2023), and IFSB-31 sets principles for supervising Shariah governance, including the use of supervisory technology supported by data security controls (IFSB, 2025). Comparative surveys show wide variation in governance practice across jurisdictions (Hasan, 2011). Bangladesh-specific studies report gaps in the governance framework and in compliance across financing modes (Alam et al., 2020; Rahman et al., 2024).

2.5 Theoretical lens

The paper combines two lenses. The first is the maqasid ends-and-means framework of Laldin and Furqani (2013), who identify wealth circulation, fair and transparent dealing, and justice as the ends of Islamic finance, and contracts, standards and institutions as the means. Smart contracts are a new means, and they must be judged by whether they serve or undermine those ends. The second is the regulation-by-code perspective of Lessig (2006) and De Filippi and Wright (2018), together with the legal critique of Werbach and Cornell (2017) and Levy (2017). Read together, the lenses lead to a design principle: code may implement rules that already have a single approved meaning, but it should not settle questions that require ijtihad, legal interpretation or discretion. The rest of the paper applies that principle function by function.

3. METHODOLOGY

3.1 Design

The study uses doctrinal-functional analysis. Doctrinal analysis identifies the binding or authoritative rules that apply to the product. Functional analysis breaks the product into the operations it must perform over its life and asks, for each operation, what inputs it needs, who decides and what happens if it fails. The approach is common in law-and-technology research on smart contracts (Governatori et al., 2018; Werbach & Cornell, 2017) and suits a question about design validity rather than prevalence or effect. The study does not collect primary data and makes no empirical claim about how Bangladeshi institutions currently operate HPSM.

3.2 Corpus and selection

The normative corpus was assembled purposively in three groups. The first group comprises Shariah and prudential standards: AAOIFI Shari'ah Standards No. 9 and No. 12 (AAOIFI, 2015) and IFSB-1, IFSB-10, IFSB-22, IFSB-30 and IFSB-31. The second comprises Bangladeshi instruments: the Guidelines for Conducting Islamic Banking issued under BRPD Circular No. 15 of 2009 (Bangladesh Bank, 2009); the Shariah Supervisory Committee directive of September 2025, which the authors could access only through press reports (The Business Standard, 2025); the IBRPD circular of September 2026 on Islamic credit cards, used as evidence of current supervisory expectations on technical Shariah controls (Bangladesh Bank, 2026); the Contract Act 1872; the Registration Act 1908; the Information and Communication Technology Act 2006; and the Cyber Security Ordinance 2025. The third is the UNCITRAL Model Law on Automated Contracting (United Nations Commission on International Trade Law [UNCITRAL], 2024), used as an international reference point. In total, the corpus contains 15 primary instruments.

Secondary literature was identified through targeted searches of publisher platforms, RePEc/IDEAS, journal websites and general scholarly search engines using combinations of "diminishing musharakah," "musharakah mutanaqisah," "smart contract," "oracle," "Islamic FinTech," "Shariah governance" and "Bangladesh." Inclusion required that a source (a) address diminishing musharakah or home finance, smart-contract law or technology, the oracle problem, Islamic FinTech, or Shariah governance; and (b) be verifiable as published, with bibliographic details confirmed against a publisher, registry or repository record. Sources that could not be verified, and sources on unrelated blockchain applications such as supply-chain management, were excluded. Twenty-eight secondary works were retained. Because the search was purposive rather than exhaustive, the study does not report PRISMA screening counts and does not claim to cover all relevant literature.

3.3 Analytical procedure

The analysis proceeded in four steps. First, the lifecycle of a diminishing musharakah home-finance transaction was divided into formation, asset acquisition, active co-ownership and lease, periodic payment and unit purchase, exceptional events, early settlement and final transfer. Second, each function was classified on three criteria. A function was rated as highly suitable for automation when (i) its inputs could be authenticated, (ii) its rule had a single interpretation approved by the Shariah board, and (iii) an error could be paused and corrected without irreversible harm. A function failing any criterion was rated partial or low. Third, each relevant AAOIFI clause was mapped to the control that would preserve it in an automated system. Fourth, the controls were organized into a state model and a layered architecture and checked against the Bangladeshi instruments. The classifications are the authors' analytical judgments. They are offered as a structured starting point for Shariah boards, lawyers and engineers, not as determinations.

4. FINDINGS AND ANALYSIS

4.1 Functional decomposition

Table 1 summarizes the classification of lifecycle functions.

Table 1. Automation suitability across the diminishing musharakah lifecycle

Lifecycle function	Nature of inputs	Automation suitability	Reason	Required control
Identity, capacity and consent	Off-chain identity; customer action	Partial	Signature can be captured digitally; understanding cannot	Verified identity; readable disclosure of material terms; separate acceptance of each linked contract
Asset identification and acquisition	Title documents, valuation, registration	Partial	Facts exist outside the ledger	Authorized oracle attestation plus legal evidence of title
Ownership-ratio arithmetic	Approved formula; confirmed payments	High	Deterministic once inputs are confirmed	Parameter registry; test cases; version control
Rent calculation	Approved rental basis; financier's units	High (fixed rent) / Partial (variable rent)	Variable rent depends on an external benchmark	Benchmark oracle with fallback; first-period rent fixed
Unit purchase pricing	Price policy approved by Shariah board	Partial	Doctrinal choice between market value and price agreed at acquisition	Board-approved pricing rule; per-purchase confirmation
Notices and statements	Contract state	High	Rule-based	Template approval; delivery logs
Late payment handling	Payment status; customer circumstances	Low for consequences; high for detection	Excuse and hardship require judgment	Automatic detection only; charity undertaking per board rules; human review
Damage, destruction, takaful claims	Physical facts; insurer decisions	Low	Facts are off-chain and contested	Pause; human determination; documented evidence
Early settlement	Customer request; pricing rule	Partial	Price and rebate questions	Board-approved formula; human sign-off
Final transfer of title	Registration and settlement evidence	Partial	Legal title is created by registration, not by the ledger	Reconciliation against registry evidence before closure
Dispute resolution	Competing claims	Low	Requires adjudication	Freeze; escalation; appeal path

Four observations follow from Table 1. The first is that the high-suitability functions are all calculation or communication tasks. Once a payment has been confirmed and the formula approved, recomputing the parties' units and the next rent amount is arithmetic. This is where automation reduces error and cost without changing the product's risk allocation.

The second is that every function touching legal title or the physical asset is only partially suitable. Title to land and apartments in Bangladesh is created and evidenced through registration, not through a ledger entry (Registration Act 1908). A smart contract can record that an authorized officer attested to a registered deed, together with the source and time of the attestation. It should not claim to create or transfer rights that the law requires to be registered elsewhere.

The third is that unit pricing, which looks like arithmetic, is in fact a doctrinal choice. Standard No. 12 permits a binding promise to acquire units at market value or at a price agreed at the time of acquisition and prohibits a promise to buy at face value (AAOIFI, 2015, SS 12, cl. 5/7, cl. 3/1/6/2). Shariah boards in different institutions have reached different practical positions on how a pre-agreed schedule relates to these rules, and the literature on Shariah governance documents such variation (Hasan, 2011). The code cannot resolve that question and should not embed an answer silently. The board's decision must be recorded as an explicit, versioned parameter.

The fourth is that consequences of default, damage and hardship cannot be safely automated. Automatic penalties, acceleration or liquidation would execute faster than any human could check whether the customer had a valid excuse or whether the asset had been destroyed. Werbach and Cornell (2017) and Levy (2017) make the general point that contract law's value lies partly in its flexibility after breach. In diminishing musharakah, the point is sharper because some outcomes are fixed by Shariah: rent cannot continue to be stipulated after total destruction of the identified asset (AAOIFI, 2015, SS 9, cl. 7/1/3).

4.2 Clause-to-control mapping

Table 2 links the Shariah requirements identified in Section 2.1 to the code-level and governance controls that preserve them.

Table 2. Mapping AAOIFI requirements to smart-contract controls

Requirement (source)	Failure mode if automated naively	Control in the automated design
Purchase promise and sale independent of the partnership contract (SS 12, cl. 5/1)	A single code module bundles partnership, lease and sale so that one acceptance creates all three	Separate contract objects and separate customer acceptances; code references each document by its own identifier
Unit price at market value or price agreed at acquisition; no face-value promise (SS 12, cl. 5/7, 3/1/6/2)	Code hard-codes an inception schedule that functions as a guaranteed buy-back at face value	Pricing rule held in the Shariah parameter registry; each unit sale generates a discrete sale record with price, date and confirmation
No capital guarantee by a partner (SS 12, cl. 3/1/4/1)	Loss events automatically debited to the customer	Loss allocation follows ownership ratio; loss events route to human review
No stipulation that one partner bears all insurance or maintenance (SS 12, cl. 5/3; SS 9, cl. 5/1/7, 5/1/8)	Code charges all takaful premiums and major repairs to the customer	Expense ledger separates ordinary and major maintenance; lessor-side costs posted to the financier
Rent specified; first-period rent fixed where variable (SS 9, cl. 5/2/1, 5/2/3)	Benchmark feed changes the current period's rent retroactively	Rent fixed at period start; benchmark changes apply prospectively; benchmark oracle with fallback
Lease ends on total destruction of identified asset (SS 9, cl. 7/1/3)	Rent and unit purchases continue after the asset is lost	Destruction event freezes rent accrual pending human determination
Late payment: charity undertaking, not income (SS 9, cl. 6/4)	Late amounts credited to the financier's income	Late-payment amounts posted to a segregated charity account under board supervision
Title-transfer method in a separate document (SS 9, cl. 8/1)	Final transfer triggered automatically by the last payment	Final transfer state requires the separate transfer instrument and registration evidence

The mapping shows that most Shariah failures in an automated product would not be coding errors in the ordinary sense. The code would do exactly what it was told. The failure would lie in the specification. This finding supports the emphasis in IFSB-10 on ex-post Shariah review and suggests that, for automated products, the review must reach the deployed logic itself (IFSB, 2009). Bangladesh Bank appears to be moving in a similar direction. Its 2026 circular on Islamic credit cards requires banks to block prohibited merchant categories through technical controls and to maintain charity accounts for late-payment donations, which treats system configuration as a Shariah control rather than an IT detail (Bangladesh Bank, 2026).

4.3 Legal decomposition for Bangladesh

The Contract Act 1872 supplies the general law of agreement, consent and enforceability. Nothing in its general principles prevents parties from using automated systems to perform agreed obligations, but the usual requirements of free consent and certainty still apply. UNCITRAL's Model Law on Automated Contracting, adopted on 11 July 2024, reflects the same position internationally: it rests on technology neutrality and non-discrimination against automated systems, sets rules for attributing system outputs, and states that automated systems cannot be used to avoid or excuse non-compliance with other legal requirements (UNCITRAL, 2024). Bangladesh has not enacted the Model Law, so it serves here as a reference rather than a binding source.

The Information and Communication Technology Act 2006 (Act No. 39 of 2006) gives legal recognition to electronic records and digital signatures. That recognition helps with evidence of consent and payment but does not override the registration regime for immovable property. Under section 17 of the Registration Act 1908, instruments that create, assign or extinguish rights in immovable property, and leases of immovable property from year to year or for more than one year, require compulsory registration. Section 17A requires a contract for the sale of immovable property to be in writing, executed and registered within thirty days of execution. Whether a particular HPSM purchase undertaking falls within section 17A depends on its drafting and is a question for transaction-specific legal opinion. The design consequence is the same in either case. The ledger can mirror the legal position but cannot replace it, and the final-transfer state must wait for registration evidence.

Cybersecurity law matters because a compromised ownership record is both a legal and a Shariah failure. The Cyber Security Ordinance 2025 (Ordinance No. 25 of 2025), gazetted on 21 May 2025, repealed the Cyber Security Act 2023 and is the current general framework for cyber offences (Cyber Security Ordinance, 2025). An institution running automated HPSM would need key management, privileged-access control and incident response consistent with that framework and with Bangladesh Bank's IT security expectations.

On the Shariah-governance side, Bangladesh Bank's 2009 guidelines allowed boards to form a Shariah Supervisory Committee and kept the board responsible for its lapses (Bangladesh Bank, 2009). According to press reports, a September 2025 directive from the Islamic Banking Regulation and Policy Department made such committees mandatory, required a Shariah ruling before any new

product is launched, required a Shariah secretariat with internal audit, compliance review and research functions, and set an annual audit plan approved by the committee, with effect from 1 January 2026 (The Business Standard, 2025). The authors were unable to retrieve the circular text, so these points are reported as described in the press. If confirmed in the official text, the pre-launch ruling and the secretariat's audit function provide a natural institutional home for the code-assurance and log-sampling controls proposed below.

4.4 Consent, disclosure and ledger design

Two further issues cut across the lifecycle. The first is consent. A digital signature can show that a customer clicked "accept," but it cannot show that the customer understood that the arrangement consists of three separate undertakings: a partnership, a lease of the financier's share, and a promise to buy units. Because Standard No. 12 requires the purchase promise to be independent of the partnership contract (AAOIFI, 2015, SS 12, cl. 5/1), the interface should present the documents separately and record a separate acceptance for each, as Table 3 below requires at state S0. A pre-ticked box, or an acceptance screen that displays only a code hash, would not meet this standard. Consent to a software update should also be kept apart from consent to a change in contractual terms. A patch that fixes a display error is an operational matter; a change to the rental basis or the unit pricing rule is a contractual and Shariah matter that needs committee approval and customer notice.

The second issue is the choice of ledger. A public blockchain offers strong tamper evidence, but it exposes transaction patterns, makes correction difficult and places personal data where it cannot be deleted. Zheng et al. (2020) list privacy and the difficulty of modifying deployed contracts among the main challenges of public smart-contract platforms. For a regulated bank product in which customers' names, property addresses and payment histories are involved, a permissioned ledger operated by the institution, or a conventional database with an append-only audit log, is the more defensible starting point. The design should keep personal data and title documents off the ledger and store only references, hashes and attestations. The value of the ledger then lies in its audit trail, not in decentralization. This conclusion matches Werbach's (2018) argument that blockchain systems relocate trust rather than eliminate it: in a bank-operated HPSM product the customer is still trusting the bank, and the architecture's task is to make that trust verifiable by the Shariah committee, auditors and supervisors.

5. PROPOSED FRAMEWORK

5.1 The transaction as a state machine

A formal state model makes the product's behavior explicit and testable. Each state represents a legally meaningful position. Each transition names its trigger, the evidence required before it may fire, the actor authorized to fire it, and whether it can be reversed.

Table 3 sets out the model.

Table 3. State-transition model for smart-contract-enabled diminishing musharakah

From state	Trigger	Guard (evidence required)	Authorized actor	Executed by	To state	Reversible?
S0 Pending formation	Customer accepts partnership, lease and purchase undertaking separately	Verified identity; disclosure acknowledged; three distinct acceptances recorded	Customer; operations officer	Code records; human verifies	S1 Acquisition pending	Yes, before funds move
S1 Acquisition pending	Joint purchase completed	Registered deed or equivalent title evidence; payment to seller confirmed; asset valuation on file	Legal officer (oracle)	Human attests; code records	S2 Active co-ownership	Only by legal process
S2 Active co-ownership	Rent period opens	Approved rental basis for the period; benchmark value captured at period start	System	Code	S2 (rent posted)	Yes, by correction transaction
S2 Active co-ownership	Unit purchase payment confirmed	Payment confirmation from bank system; pricing rule	Customer; system	Code	S2 (units updated)	Yes, by correction transaction

From state	Trigger	Guard (evidence required)	Authorized actor	Executed by	To state	Reversible?
		version; customer confirmation of the unit sale				
S2 Active co-ownership	Payment overdue beyond grace period	Payment system shows non-receipt	System detects; officer reviews	Code flags; human decides	S3 Arrears review	Yes
S3 Arrears review	Review concluded	Officer's determination with reasons; charity undertaking applied only if delay unexcused	Credit officer; Shariah secretariat for charity posting	Human decides; code posts	S2 or S6 Dispute/freeze	Yes
S2 Active co-ownership	Damage, destruction or force majeure reported	Report from customer, insurer or surveyor	Customer; insurer; officer	Code pauses rent accrual	S4 Asset event review	Yes
S4 Asset event review	Determination issued	Surveyor or takaful report; Shariah view on rent and loss allocation	Operations; Shariah secretariat	Human decides; code applies	S2, S5 or S8	Partly
S2 Active co-ownership	Early settlement requested	Customer request; board-approved settlement formula	Customer; officer	Code calculates; human approves	S5 Final transfer pending	Yes, before settlement
S2 Active co-ownership	Financier's units reach zero	All unit sales recorded and reconciled	System	Code	S5 Final transfer pending	Yes
S5 Final transfer pending	Title transfer completed	Separate transfer instrument executed; registration evidence; settlement reconciled	Legal officer	Human attests; code records	S7 Closed	No
Any state	Dispute raised or oracle conflict detected	Complaint record or conflicting feeds	Customer; system; officer	Code freezes automated actions	S6 Dispute/freeze	Yes
S6 Dispute/freeze	Resolution recorded	Decision of authorized body; appeal window elapsed	Dispute officer; Shariah committee where relevant	Human decides; code resumes	Prior state or S8	Per decision
S4 Asset event review	Total destruction confirmed	Surveyor report; takaful outcome	Operations; Shariah secretariat	Human decides	S8 Terminated (loss settled by ownership ratio)	No

Note: S7 (Closed) and S8 (Terminated) are terminal states. Unauthorized transitions must fail safely, leaving the contract in its prior state and generating an alert.

Three design rules follow from the model. First, no transition that affects title, loss allocation or customer liability fires on code alone. Code may detect, calculate and propose, but a named human role must authorize. Second, every state that can be entered automatically can be exited by a correction transaction that leaves the original record intact. This preserves the audit value of an append-only log while allowing errors to be fixed. Third, an oracle conflict, such as a payment confirmation that disagrees with the

core banking system, moves the contract into the dispute/freeze state rather than letting the code choose between sources. This applies Caldarelli's (2020) point that oracle trust must be managed explicitly.

Test suites should cover boundary dates, rounding, partial and duplicate payments, payment reversal, benchmark outages, inconsistent oracle reports and every illegal transition. Atzei et al. (2017) show that many smart-contract failures arise from unanticipated execution paths, so negative tests that try to force forbidden transitions matter as much as positive ones.

5.2 The six-layer control architecture

The architecture separates the product into six layers, each with its own owner and assurance mechanism (Table 4).

Table 4. Six-layer control architecture

Layer	Content	Owner	Primary assurance	Failure it prevents
1. Legal prose	Partnership, lease, purchase undertaking and transfer instruments; precedence clause; governing law; dispute process; plain-language description of automated functions	Legal department	Legal opinion; disclosure review	Code treated as the whole contract
2.Shariah parameter registry	Approved formulas, unit pricing rule, rental basis, rounding, charity treatment, event definitions, version history	Shariah Supervisory Committee via secretariat	Committee resolution per version; change log	Unapproved rules entering code
3. Executable code	Deterministic actions only: ratio updates, rent and unit calculations, notices, logging, state transitions	Technology unit	Independent code audit; test evidence	Logic errors; exploitable paths
4. Oracle and evidence service	Authenticated feeds for payments, benchmark rates, title events, valuations, insured and physical events; source hierarchy and fallback	Operations	Source reconciliation; dual control for title attestations	Wrong or manipulated off-chain facts
5. Governance	Access control, separation of duties, key management, change management, cybersecurity monitoring, internal Shariah review, internal audit	Risk, IT security, internal audit, Shariah secretariat	Separation of duties; incident response; log sampling	Unauthorized change; undetected drift
6. Remedy	Pause, human review, correction transaction, dispute escalation, customer appeal, compensation	Operations and dispute function	Traceable correction; appeal records	Irreversible harm from automated action

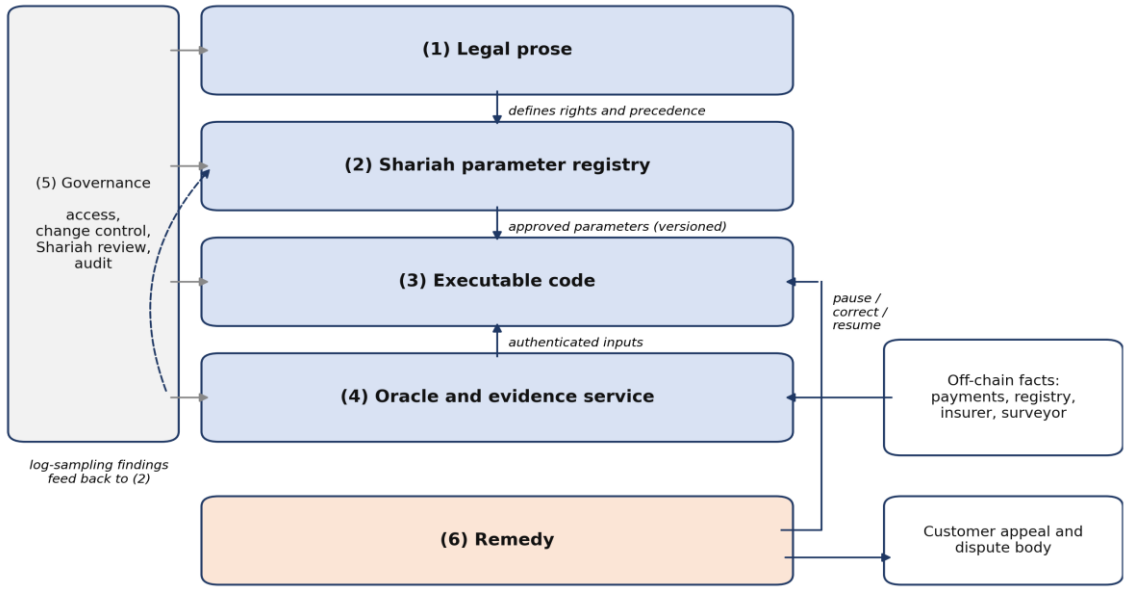


Figure 1 shows how the six layers interact.

Figure 1. Six-layer control architecture for smart-contract-enabled diminishing musharakah

Source: Authors' own elaboration.

Layer 1: legal prose. The signed agreements remain the source of rights. They should state which document governs if code and text diverge, describe the automated functions in plain language, and set out the dispute process. Disclosure of how the product works and where its risks lie should follow the transparency expectations that IFSB-22 sets for Islamic banks (IFSB, 2018). A precedence clause is necessary but not sufficient, because by the time a divergence is noticed the code may already have acted. The remedy layer exists for that reason.

Layer 2: Shariah parameter registry. Every rule the code uses, including the unit pricing rule, the rental basis, rounding, grace periods and the charity account mapping, is held as a named parameter with a version number, the resolution approving it and its effective date. Changes apply prospectively and are communicated to customers. The registry makes the Shariah committee's decisions machine-readable without asking the code to interpret them.

Layer 3: executable code. Code is limited to deterministic actions that satisfy the three criteria in Section 3.3. It reads parameters from the registry rather than containing them, so that a parameter change does not require a code change and a code change cannot silently alter a Shariah rule.

Layer 4: oracle and evidence. Each off-chain fact has a primary source, a secondary source and a rule for conflicts. Payments come from the core banking or payment system. Benchmark rates come from a named publisher with a fallback. Title events require attestation by a legal officer with dual control. Physical and insured events require a report from an identified surveyor or takaful operator. The ledger records the attestation and its source. It does not hold personal data or title documents on a public chain.

Layer 5: governance. Separation of duties is the core control. Product designers define requirements; the Shariah committee approves the logic; lawyers confirm enforceability; developers implement; independent specialists test; operations validate off-chain evidence; auditors compare execution with approved logic. No role can both change code and approve that change. IFSB-1's treatment of Shariah non-compliance as operational risk supports placing these controls inside the operational risk framework rather than in a separate technology silo (IFSB, 2005).

Layer 6: remedy. The system must be able to pause automated actions for one contract or for the whole product, to correct records through visible correction transactions, and to resume. Customers need a route to challenge automated outcomes and a non-digital channel when disability, outage or lost credentials prevent access. Werbach and Cornell (2017) argue that contract law's remedial function cannot be designed away. This layer keeps it in the product.

5.3 Shariah assurance of deployed logic

Shariah assurance for an automated product should trace each executed action back to an approved rule. A deployment package should contain the signed agreement templates, the committee resolutions, the parameter registry, the source-code version and hash, the independent code audit, the test evidence and the operating procedures. After launch, the internal Shariah review should sample event logs and check that rent, unit purchases, charity postings and ownership updates follow the approved parameters. This extends the ex-post review in IFSB-10 from documents to execution (IFSB, 2009). A readable execution report, linking each automated action to its contract clause and parameter version, would let Shariah reviewers do this without reading code.

The same logic applies to any use of artificial intelligence in the product, for example to triage hardship requests or classify asset events. Such tools may support human reviewers but should not issue determinations on Shariah or customer liability (Billah & Zahid, 2026).

5.4 Implementation path for Bangladesh

A prudent first deployment would use a permissioned ledger or a controlled automation layer within the bank's own systems, applied to a narrow asset class such as registered apartments in a single city. The bank should run the automated process in parallel with existing HPSM administration until reconciliation is reliable. The Shariah ruling required before launch should cover the parameter registry and the state model, not only the contract templates. Engagement with Bangladesh Bank should precede customer deployment, especially where automated postings interact with payment systems.

The pilot should test normal and exceptional scenarios: missed payments, payment reversals, rent review, early unit purchase, damage, disputed oracle input, system outage and customer complaints. Success criteria should include reconciliation accuracy, time taken to apply a remedy, customer understanding of disclosures and the number of Shariah exceptions found in log sampling. Transaction speed alone is a poor measure, since the product's long tenor makes speed less valuable than accuracy.

6. DISCUSSION

The findings answer the three research questions as follows. For RQ1, the functions that can be automated without compromising Standards No. 9 and No. 12 are the arithmetic and communication functions: ownership-ratio updates, fixed-basis rent calculation, notices and evidence logging. For RQ2, functions touching title, the physical asset, unit pricing policy, arrears consequences, destruction and disputes require human authority supported by documented evidence. For RQ3, the six-layer architecture and the

state model translate these results into controls that sit within Bangladesh's registration, electronic-records, cybersecurity and Shariah-governance framework.

These results refine the optimism found in parts of the Islamic FinTech literature. Reviews often present blockchain and smart contracts as tools that improve transparency and reduce cost (Alam et al., 2019; Rabbani et al., 2020). The analysis here agrees that the gains are real for calculation and record-keeping but finds that the Shariah risk of an automated product sits mainly in specification and oracle design, not in the ledger. This is consistent with Hamza's (2020) finding that smart sukuk structures inherit the Shariah questions of their underlying contracts, and with the view of Zulkepli et al. (2026) that coding and execution need juristic attention in their own right.

The findings also give concrete form to the law-and-technology critique. Levy's (2017) observation that contracts depend on flexibility appears here as the arrears and asset-event review states. Werbach and Cornell's (2017) insistence on remedies appears as Layer 6. Caldarelli's (2020) oracle problem appears as Layer 4 and as the rule that conflicting feeds freeze the contract. Lessig's (2006) claim that code regulates appears in the decision to keep Shariah rules in a registry governed by the Shariah committee rather than in code written by developers.

For the diminishing musharakah literature, the analysis adds an operational argument to the established doctrinal one. Smolo and Hassan (2011) and Meera and Abdul Razak (2005) argued that the structure aligns finance with ownership. That alignment survives automation only if the code preserves the financier's exposure to asset risk: lessor-side maintenance and insurance costs, loss allocation by ownership ratio, and the end of rent on destruction. El-Gamal's (2006) concern about form over substance becomes, in an automated product, a concern about whether the code's actual behavior matches the contract's stated allocation. The risk-sharing rationale for the product (Zahid et al., 2025) is therefore something to be tested in event logs, not assumed from documentation.

For Bangladesh, the findings connect to evidence of governance gaps. Alam et al. (2020) attributed the lack of a comprehensive Shariah governance framework partly to a shortage of experts, and Rahman et al. (2024) found significant non-compliance in several financing modes. Automation could either reduce such problems, by enforcing approved rules consistently, or magnify them, by repeating an unapproved rule across a portfolio. Which outcome occurs depends on the governance layers more than on the technology.

7. IMPLICATIONS

7.1 Theoretical implications

The paper offers a way to apply the maqasid ends-and-means framework (Laldin & Furqani, 2013) to digital product design. Smart contracts are treated as means whose legitimacy depends on whether they preserve the risk allocation and fairness that the contract is meant to achieve. Combined with the regulation-by-code perspective, this yields a testable criterion for automation: a function may be automated when its inputs are authenticated, its rule has a single approved meaning, and its errors are correctable. The criterion can be applied to other Islamic contracts with lifecycle complexity, such as ijarah muntahia bittamleek, istisna' and musharakah-based working-capital facilities.

7.2 Practical implications

For Islamic banks and financial institutions, the main implications are organizational. Shariah secretariats will need staff or advisers who can read state models, parameter registries and test reports. Product teams should design the parameter registry before writing code. Technology teams should treat Shariah parameters as configuration owned by the Shariah committee. Internal audit should add event-log sampling to its Shariah review programme. Customer statements should show the economic position (the customer's units, the financier's units, the rental basis, the unit price applied, outstanding amounts and any exceptional status) rather than a list of technical events.

7.3 Policy implications

For Bangladesh Bank, three steps would support safe adoption. First, guidance on new-product Shariah approval could specify that, for automated products, the approval covers the deployed logic and parameter registry as well as the documents. Second, supervisors could require parallel running, pause-and-correct capability and independent code assurance before approving automated HPSM at scale. Third, the supervisory technology contemplated by IFSB-31 (IFSB, 2025) could be used to receive execution reports directly. Coordination with land-registration authorities would be needed before any link between ledger records and the land registry could be considered.

8. LIMITATIONS AND FUTURE RESEARCH

The study has several limitations. It is doctrinal and conceptual. It does not test a prototype, measure costs or survey practitioners, and its automation ratings are analytical judgments that Shariah scholars, lawyers and engineers may reasonably contest. It relies on

the 2015 compilation of AAOIFI Shari'ah Standards; later amendments should be checked against the authoritative current text. The September 2025 Bangladesh Bank directive on Shariah Supervisory Committees was available to the authors only through press reports. The analysis of the Registration Act and the ICT Act identifies issues but does not resolve them; transaction-specific legal opinions would be needed. The corpus was purposive and may have missed relevant work, particularly in Arabic and Malay.

Future research could build and test a regulator-observed prototype of the state model, subject the code to independent security review and Shariah review, and measure reconciliation accuracy and time to remedy against manual administration. Structured consultation with Shariah committee members and lawyers in Bangladesh, using methods such as the Delphi technique, could test and refine the automation ratings in Table 1. Comparative work across jurisdictions with different land-registration systems would show how far the architecture generalizes. Research on customer comprehension of automated statements, including among customers with limited digital literacy, would help ensure that automation does not weaken informed consent.

9. CONCLUSION

Smart contracts can make diminishing musharakah easier to administer accurately, but only if automation stays subordinate to valid contracts, authenticated facts and accountable judgment. The analysis shows that the product's arithmetic and record-keeping suit automation, while its title, asset, pricing-policy, arrears and dispute functions do not. The proposed six-layer architecture separates legal prose, Shariah parameters, code, oracles, governance and remedy, and the ten-state model makes every transition explicit, evidenced and, where possible, reversible. For Bangladesh, where HPSM is an established product and Shariah governance requirements are tightening, the architecture offers a practical route to automation that keeps ownership risk with the owner, keeps Shariah interpretation with qualified scholars and keeps legal title in the registry where the law places it.

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