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Comparative Analysis of the Challenges in the Enforcement of Judicial Judgments and Arbitral Awards on Public Blockchain Networks: A Perspective from UNCITRAL and Iranian Law

Peyman Moradi[1], Ghazaleh Kabirabadi[2]*, Majid Dehghan Chenari[3], Mohammad Amini[4]

[1] Department of Law, Ya.C., Islamic Azad University, Yazd, Iran
[2] Assistant Professor, Department of Law, Y.C., Islamic Azad University, Yazd, Iran
[3] Department of Law, Bafg.C., Islamic Azad University, Bafgh, Iran
[4] Department of Computer, Ya.C., Islamic Azad University, Yazd, Iran

*** Corresponding author email address**: Ghazaleh.kabirabadi@iau.ac.ir

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The comparative analysis of the challenges associated with the enforcement of judicial judgments and arbitral awards on public blockchain networks constitutes an emerging field at the intersection of international commercial law and distributed ledger technologies (DLT). It examines the extent to which sovereign and judicial authority may be exercised over digital assets within decentralized environments. The central issue addressed in this study is the fundamental conflict between the intrinsic characteristics of public blockchains—such as immutability, pseudonymity, and their inherently cross-border nature—and the enforcement requirements of judicial and arbitral systems, which traditionally rely upon third-party intervention, territorial jurisdiction, and the possibility of reversing or invalidating transactions. In the absence of a central authority, public blockchain networks present significant technical and legal obstacles to the compulsory seizure, transfer, or execution against digital assets. Employing a descriptive-analytical methodology with a comparative legal approach, this research examines the legal instruments and proposed frameworks developed by the United Nations Commission on International Trade Law (UNCITRAL), including the Model Law on Electronic Commerce and the Model Law on Electronic Transferable Records, and compares them with the relevant provisions of Iranian legislation, particularly the Civil Judgments Enforcement Act and the Electronic Commerce Act. The identified research gap arises from the predominant focus of previous scholarship on the legal nature of smart contracts, while largely overlooking the operational complexities of enforcing judicial and arbitral decisions at the technical layer of blockchain systems. Addressing this gap is essential to ensuring legal certainty for stakeholders and maintaining transactional stability within the digital economy. The findings indicate that, notwithstanding UNCITRAL's recognition of the principle of functional equivalence, a substantial gap remains between the legal validity of judicial judgments and arbitral awards and their technical enforceability on public blockchain networks. Likewise, under Iranian law, the absence of a comprehensive legal framework defining digital assets as property, coupled with the lack of statutory mechanisms enabling judicial access to private cryptographic keys, significantly undermines the effectiveness of traditional enforcement procedures. The study ultimately recommends that, in order to align the Iranian legal system with global technological developments, concepts such as judicial oracles and governable smart contracts should be formally recognized, while the necessary technical infrastructure should be established to facilitate direct interaction between judicial authorities and decentralized blockchain networks.

Keywords: *Public Blockchain, Enforcement of Judgments, UNCITRAL, Digital Arbitration, Smart Contracts, Iranian Law.*

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1. Introduction

The emergence of blockchain technology as a distributed, decentralized, and immutable ledger has fundamentally transformed traditional legal and commercial paradigms. Initially introduced as a mechanism for facilitating peer-to-peer digital payments without intermediaries, blockchain has evolved into one of the foundational infrastructures of the emerging global digital economy (Nakamoto, 2009). Its defining characteristics—including transparency, enhanced cybersecurity, and, most significantly, decentralization—have created unprecedented challenges for legal systems traditionally grounded in the authority of nation-states and territorially based judicial jurisdiction. Within this context, the enforcement of judgments, as the final and most critical stage in the administration of justice, faces some of the most complex legal and technical obstacles.

The enforcement of judicial judgments and arbitral awards traditionally presupposes the existence of state coercive power capable of seizing assets, freezing accounts, or compelling the transfer of ownership. Public blockchain networks, however, operate under an entirely different paradigm. Digital assets are controlled exclusively through private cryptographic keys, while transactions are authenticated by digital signatures and permanently recorded on a decentralized ledger. Because no central authority possesses the ability to access, alter, or invalidate confirmed transactions, conventional enforcement mechanisms become largely ineffective. This reality gives rise to the principal research question of the present study: How can the challenges associated with the enforcement of judicial judgments and arbitral awards on public blockchain networks be analyzed under the legal frameworks of UNCITRAL and Iranian law, and what alternative or complementary enforcement mechanisms may be developed? The significance of this inquiry stems from the growing tension between the rule of law and the increasingly influential notion of the rule of code. Legal scholars have argued that smart contracts substantially reduce transaction costs by automating contractual performance. Nevertheless, their inherent inability to respond to unforeseen circumstances or accommodate the enforcement of external judicial or arbitral decisions prevents them from functioning as comprehensive legal systems (Lester, 2018). Existing legal scholarship has predominantly concentrated on the substantive legal nature of smart contracts and cryptocurrencies, while paying comparatively little attention to the procedural and enforcement-related issues arising at the technical layer of blockchain networks. Although numerous studies have examined the legal status of crypto-assets, relatively few have addressed the practical question of how a judicial judgment may be effectively enforced against decentralized digital assets once such a judgment has been rendered. By addressing this gap, the present research seeks to demonstrate that, without integrating technical blockchain concepts into the legal framework, judicial certainty within the digital environment cannot be adequately safeguarded.

At the international level, the United Nations Commission on International Trade Law (UNCITRAL) has consistently pursued a technology-neutral approach in its efforts to harmonize the legal framework governing electronic commerce. According to this principle, legal systems should refrain from favoring any particular technology and should instead recognize the functional equivalence of different technological solutions (H. Shahrami, 2024). However, this principle encounters significant limitations when applied to public blockchain networks, where decentralization fundamentally challenges conventional notions of accountability and legal responsibility.

The principal hypothesis of this research is that, although Iranian law recognizes the general principles governing electronic commerce, it lacks comprehensive legal and technical mechanisms capable of facilitating the enforcement of judicial judgments and arbitral awards within public blockchain environments. This regulatory deficiency cannot be adequately remedied through an expansive judicial interpretation of existing legislation or by merely adopting UNCITRAL's model frameworks. Rather, it necessitates the enactment of dedicated legislation recognizing digital assets as property capable of judicial seizure and establishing legal infrastructures for implementing judicial enforcement oracles capable of bridging judicial decisions and blockchain execution.

Network governance theory further suggests that, in the digital age, geographical boundaries have lost much of their traditional legal significance. Consequently, governance over digital assets and data requires regulatory instruments extending beyond conventional

law enforcement institutions and judicial officers (Lash, 2000). Within the Iranian legal system, although the Electronic Commerce Act of 2003 recognizes electronic documents and electronic signatures, it remains entirely silent regarding blockchain-based assets and the mechanisms necessary for their judicial enforcement. This legislative silence has generated considerable uncertainty concerning both the competent judicial authorities and the applicable enforcement procedures. For instance, where a judgment debtor stores cryptocurrency in a cold wallet secured exclusively by private keys, Iranian enforcement authorities currently possess no legal or technical means of accessing those assets. This practical reality illustrates the urgent necessity of redefining the concept of civil enforcement within the context of decentralized digital property.

Beyond the technical dimension, arbitration law presents additional challenges. International commercial arbitration has rapidly adapted to technological innovation; nevertheless, the recognition and enforcement of digital arbitral awards within decentralized blockchain environments continue to raise significant legal questions. In its guidance concerning electronic arbitration, UNCITRAL acknowledges that parties may employ smart contracts to facilitate the automatic execution of arbitral awards. However, such automation presupposes that all relevant enforcement conditions have been comprehensively incorporated into the original contractual framework—an assumption that is frequently unrealistic in commercial practice (Sarvar, 2024). Consequently, an intermediary layer capable of translating legally binding decisions into executable blockchain code becomes indispensable. Through a comparative examination of Iranian law and UNCITRAL instruments, this study explores how governable smart contracts may provide a legal and technical framework permitting judicial intervention whenever contractual violations or enforcement disputes arise.

Finally, the selection of this research topic is justified not only by its academic contribution to the expanding literature on information technology law but also by its practical implications for enhancing foreign investment and strengthening confidence in Iran's judicial system within the digital economy. Unless the existing enforcement obstacles are effectively addressed, economic actors are unlikely to rely on domestic blockchain platforms, since uncertainty regarding judicial remedies and the practical enforceability of legal decisions substantially increases transactional risk. Accordingly, the integration of law and blockchain technology should no longer be regarded as a matter of policy preference but rather as an indispensable legal necessity in the era of decentralized digital infrastructure.

2. Conceptual Foundations and the Substantive Tension Between Public Blockchain Networks and Traditional Enforcement Systems

The conceptual foundations of public blockchain networks rest upon three fundamental principles—immutability, decentralization, and transparency—each of which independently poses significant challenges to traditional enforcement regimes. Conventional legal systems operate on the premise that judicial decisions remain subject to amendment, reversal, suspension, or modification whenever necessary to ensure that justice is administered dynamically and in accordance with evolving factual circumstances. Public blockchains, by contrast, permanently record transactions once they have been validated through the network's consensus mechanism, rendering them technically immutable and resistant to subsequent alteration (Samiei, 2023). Although this feature substantially enhances cybersecurity and transactional integrity, it simultaneously deprives judicial authorities of the flexibility required to enforce court judgments effectively.

For example, where a court orders the recovery of assets obtained through fraud, conventional enforcement authorities may freeze bank accounts or seize property held by the judgment debtor. Within a public blockchain environment, however, no centralized entity possesses the authority to freeze assets or reverse transactions, as digital assets remain exclusively controlled through private cryptographic keys. Consequently, a fundamental conflict arises between the legal principle permitting judicial correction and the technological principle of irreversible transaction finality, creating a substantial gap in the practical enforceability of judicial decisions (Mohammadi-Najad, 2024). The decentralized architecture of public blockchains further implies the absence of any intermediary institution or service provider bearing ultimate legal responsibility. Under

traditional enforcement systems, accountability constitutes an indispensable prerequisite for identifying defendants and exercising coercive enforcement measures. In decentralized blockchain networks, however, users frequently operate anonymously or pseudonymously, thereby complicating the identification of wrongdoers and the localization of their assets (Ahmadi, 2023). Decentralization fundamentally transforms conventional concepts of ownership and control by shifting ownership from formal registration within governmental registries or financial institutions to exclusive possession of private cryptographic keys. Within Iranian law, as in many other legal systems, judicial enforcement ordinarily presupposes the existence of identifiable assets or accounts subject to governmental supervision and judicial attachment. Blockchain assets, however, are typically maintained within privately controlled digital wallets distributed across multiple jurisdictions worldwide. This technical and geographical dispersion significantly challenges the traditional territorial principle governing judicial jurisdiction, since a judgment rendered by an Iranian court cannot readily produce legal effects upon digital assets processed through blockchain nodes operating in foreign jurisdictions (Karimi, 2022).

Moreover, the inherent transparency of blockchain technology, which enables any participant to examine the complete transactional history recorded on the ledger, presents an additional legal dilemma. While transparency undoubtedly enhances regulatory oversight and transactional accountability, it simultaneously conflicts with the legal obligation to protect the privacy and confidentiality of parties involved in judicial proceedings. Traditional enforcement mechanisms generally preserve the confidentiality of sensitive financial information. Public blockchains, however, permanently expose the historical movement of digital assets, potentially facilitating unauthorized profiling or infringing individual privacy rights, notwithstanding the pseudonymous nature of blockchain addresses. Accordingly, the substantive conflict between public blockchain networks and traditional enforcement systems extends far beyond technical incompatibility. It encompasses fundamental divergences regarding the concepts of justice, accountability, legal authority, and sovereignty. Recent scholarship suggests that unless these conceptual differences are comprehensively analyzed and accompanied by context-specific legal solutions, attempts to impose traditional legal doctrines upon emerging decentralized technologies will merely generate additional legal uncertainty while diminishing the effectiveness of judicial institutions (Rahimi, 2024). Public blockchains therefore represent a fundamentally distinct paradigm from conventional legal and financial systems, and understanding this distinction constitutes an indispensable prerequisite for any meaningful legislative reform or modernization of enforcement procedures.

2.1. Analysis of Immutability and the Challenge of Reversing or Modifying Transactions in Judgment Enforcement

Immutability, one of the defining characteristics of public blockchain technology, serves as the principal foundation for security and trust within decentralized networks. At the same time, it creates a fundamental paradox when juxtaposed with the flexible nature of judicial enforcement. Immutability signifies that, once validated through the network consensus mechanism and recorded on the distributed ledger, a transaction cannot be technically deleted, altered, or reversed. While this characteristic effectively prevents fraud and unauthorized manipulation, it simultaneously creates substantial obstacles whenever judicial authorities seek to recover misappropriated assets, suspend pending transfers, or restore parties to their original legal positions (Purhashemi, 2023). Traditional legal systems recognize the inherent authority of courts to alter the legal status of property through provisional or final judicial orders. Public blockchains, however, provide no native mechanism through which such judicial intervention can be technically implemented, as no centralized authority exists with the power to modify confirmed transactions.

The practical implications of this limitation become particularly evident when a judgment debtor rapidly transfers digital assets before enforcement authorities are able to intervene. Even where investigators successfully identify the responsible individual, the absence of access to that person's private cryptographic keys renders asset recovery practically impossible unless the individual voluntarily cooperates (R. Shahrami, 2024). Consequently, although technical immutability does not necessarily imply legal

immutability, existing legal institutions lack effective mechanisms capable of translating legally binding judicial decisions into corresponding technical modifications within blockchain infrastructure.

Empirical studies further demonstrate that victims of cryptocurrency fraud frequently remain unable to recover their assets despite obtaining favorable judicial judgments, since the relevant transactions have already been permanently recorded on the blockchain and no protocol-level mechanism exists for reversing the ledger's historical state (Kariminezad, 2023). Rather than compensating for legislative deficiencies, this technological limitation highlights the necessity of developing intermediary enforcement mechanisms, including judicial enforcement oracles capable of automatically implementing court orders through governable smart contracts.

Nevertheless, even the implementation of such intermediary mechanisms cannot eliminate the fundamental difficulty posed by transaction finality at the protocol level. Consequently, legal and technical scholars have increasingly debated the possibility of introducing selective reversibility mechanisms or address-freezing capabilities within lower-layer blockchain protocols, notwithstanding the apparent inconsistency of such proposals with the philosophical foundations of decentralized blockchain governance (Ahmadvand, 2022).

From a legal perspective, judicial orders directing the modification or deletion of blockchain transactions remain practically unenforceable unless intermediary platforms, custodial wallet providers, or centralized service providers voluntarily cooperate. Such reliance upon centralized actors, however, reintroduces precisely the centralized structures that blockchain technology was originally designed to eliminate. The resulting tension between technological immutability and legal adaptability therefore remains one of the most significant unresolved questions confronting contemporary digital asset regulation.

Within the Iranian legal system, legislative silence regarding this issue has produced a practical tendency for courts to issue monetary compensation orders rather than directing the attachment of specific crypto-assets. This approach reflects the practical impossibility of seizing uniquely identified blockchain assets within an immutable decentralized environment (Medavi-Kia, 2024). Although this practice provides a pragmatic workaround, it may ultimately undermine substantive justice, since judgment creditors frequently fail to receive assets equivalent to those originally lost. Accordingly, analysis of blockchain immutability demonstrates that, unless blockchain protocols evolve to incorporate controlled mechanisms for judicial freezing or conditional reversibility, the enforcement of judicial judgments within public blockchain ecosystems will continue to encounter significant practical limitations. Legal systems will consequently remain compelled either to tolerate substantial enforcement failures or to construct increasingly complex legal exceptions capable of reconciling technological constraints with traditional legal doctrines. Addressing this challenge requires far closer collaboration between software engineers, blockchain architects, and legal scholars in designing decentralized infrastructures capable of accommodating legitimate judicial intervention through indirect yet legally effective mechanisms.

2.2. The Conflict Between the Cross-Border Nature of Blockchain and the Territorial Principle of Judicial Jurisdiction

The conflict between the inherently cross-border architecture of blockchain technology and the territorial principle governing judicial jurisdiction constitutes one of the most complex legal challenges of the digital era. This conflict originates from the decentralized nature of blockchain networks and the global distribution of their validating nodes. Under traditional legal systems, judicial jurisdiction and the enforcement of judgments are intrinsically linked to state sovereignty, such that judicial decisions are generally enforceable only within the territorial boundaries of the issuing state unless recognition and enforcement procedures are undertaken abroad (Nouri, 2023). Public blockchain networks, however, possess no identifiable physical center. Their validating nodes operate simultaneously across numerous jurisdictions, making it exceedingly difficult to determine the governing law applicable to a particular blockchain transaction or smart contract. Consequently, where an Iranian court renders a judgment involving digital assets maintained in wallets controlled from foreign jurisdictions or validated through overseas blockchain nodes, enforcement becomes subject to substantial diplomatic, jurisdictional, and procedural

obstacles (Partoo, 2024). These difficulties become even more pronounced where litigants conceal their true identities or where their geographical locations cannot be reliably determined. Under such circumstances, the territorial principle—which traditionally depends upon identifying both the defendant and the location of the relevant property—loses much of its practical effectiveness.

Recent scholarship indicates that this incompatibility has effectively created legal safe havens, enabling judgment debtors to avoid enforcement by transferring digital assets to jurisdictions lacking mutual judicial assistance agreements or by maintaining cryptocurrency in cold wallets located beyond the practical reach of domestic enforcement authorities (Rastgar, 2023).

From the perspective of private international law, cross-border enforcement ordinarily requires formal recognition and validation of foreign judgments by the courts of the requested state. Blockchain transactions, however, are executed instantaneously and without intermediaries, thereby rendering traditional recognition procedures too slow to prevent the rapid dissipation of digital assets. Consequently, a fundamental conflict emerges between the speed and borderless nature of blockchain technology and the comparatively fragmented and procedurally complex framework of private international law.

Within Iranian law, existing civil procedure legislation was drafted upon assumptions reflecting conventional forms of tangible property and therefore contains no mechanisms for expedited international asset tracing or the identification of active blockchain nodes (Samiei, 2024). As a consequence, judicial decisions involving crypto-assets frequently possess little practical enforceability beyond Iran's borders unless supported by bilateral judicial cooperation agreements—a mechanism that remains unavailable with many technologically advanced jurisdictions. An additional challenge concerns determining the legal situs of blockchain transactions or digital misconduct. A single blockchain transaction may originate from a node located in Japan and be validated by nodes operating in Germany, while both contracting parties reside in Iran. Such geographical dispersion fundamentally challenges the territorial principle of jurisdiction and suggests that future jurisdictional doctrines may need to evolve from physical location-based criteria toward algorithmic, functional, or network-oriented connecting factors (Ahmadi, 2022). Contemporary legal systems, however, remain largely unprepared to embrace such a paradigm shift and continue to emphasize conventional territorial connecting factors. This jurisdictional conflict not only complicates the enforcement of judicial judgments but also undermines investor confidence and public trust in judicial institutions operating within the digital economy. Potential solutions include the development of internationally harmonized legal frameworks, particularly those promoted by UNCITRAL, capable of establishing uniform jurisdictional standards for digital assets and decentralized commercial activities. Until such frameworks achieve widespread international acceptance, however, the gap between domestic legal systems and the technological realities of blockchain networks will continue to persist. This situation underscores the urgent necessity of reexamining traditional concepts of sovereignty and judicial jurisdiction within an increasingly decentralized digital environment, while recognizing that fragmented national approaches alone are unlikely to resolve what has become an inherently global legal challenge.

3. UNCITRAL's Approach to Digital Assets and Ensuring the Enforceability of Judicial Judgments and Arbitral Awards

The United Nations Commission on International Trade Law (UNCITRAL), as the principal international body responsible for the harmonization and modernization of international trade law, has undertaken extensive efforts to develop legal standards addressing digital assets and blockchain technology. UNCITRAL's regulatory philosophy is fundamentally grounded in two complementary principles: technology neutrality and functional equivalence. These principles seek to ensure that electronic records and digital transactions are not denied legal validity or enforceability solely because they exist in electronic form (Sadeghi, 2022).

Within the context of public blockchain networks, UNCITRAL endeavors to bridge the conceptual divide between traditional notions of property ownership and the emerging realities of digital asset governance. Among its most significant legislative achievements is the UNCITRAL Model Law on Electronic Transferable Records (MLETR), adopted in 2017, which replaces the traditional concept of physical possession with the legal

concept of control. Under this framework, possession of a private cryptographic key or exclusive access to the credentials required to authorize blockchain transactions constitutes legal control over the corresponding digital asset. This conceptual shift enables judicial systems to focus upon the transfer and allocation of digital control rather than upon physical possession of tangible property (Habibi, 2023).

Despite this significant conceptual development, ensuring the effective enforcement of judicial judgments and arbitral awards within decentralized blockchain environments remains a substantial legal and technical challenge. In the reports of its specialized working groups, UNCITRAL has recognized that effective judicial enforcement requires legal systems to translate judicial orders into formats capable of interacting with blockchain protocols and smart contract architectures. Rather than advocating the immediate enactment of entirely new legislation, UNCITRAL generally favors interpreting existing legal frameworks in a manner that recognizes tokenized digital assets as property capable of judicial attachment and execution (Bagheri, 2024).

From UNCITRAL's perspective, international cooperation among states is indispensable for the recognition and enforcement of cross-border judgments within decentralized environments. Because blockchain networks operate without territorial boundaries, unilateral enforcement measures adopted by a single state frequently prove ineffective. Consequently, UNCITRAL emphasizes the necessity of developing common technical standards enabling judicial authorities to communicate enforcement instructions to blockchain infrastructures through mechanisms such as judicial oracles or supervisory nodes.

Recent Iranian legal scholarship likewise suggests that harmonization with UNCITRAL's approach requires substantial reform of the Electronic Commerce Act, including the explicit recognition of blockchain-based assets as collateral and as property subject to judicial execution (Maleki, 2024). Ultimately, UNCITRAL seeks to establish legal certainty for commercial actors by ensuring that judicial judgments and arbitral awards involving digital assets do not become practically unenforceable merely because of the technological architecture of public blockchain networks.

This evolutionary regulatory approach demonstrates that, unlike certain restrictive domestic legal models, UNCITRAL favors integrating technological innovation into the broader framework of international commercial law in order to preserve the effectiveness of judicial enforcement in the digital economy (Bagheri, 2024). The long-term success of this strategy, however, depends upon the widespread adoption of UNCITRAL's model instruments by national legislatures and the development of the technical infrastructure necessary to facilitate interaction between judicial institutions and distributed ledger systems, thereby reducing transactional risk within the global digital economy.

3.1. Reinterpreting the Principles of Technology Neutrality and Functional Equivalence in Modern UNCITRAL Instruments

The principles of technology neutrality and functional equivalence constitute the two fundamental pillars of the modern legislative instruments developed by the United Nations Commission on International Trade Law (UNCITRAL). Together, these principles establish the theoretical framework through which emerging technologies, including blockchain and distributed ledger systems, may be accommodated within contemporary legal systems.

The principle of technology neutrality requires that legal rules neither favor nor discriminate against any particular technological solution. Rather than prescribing specific technologies, legislation should remain sufficiently flexible to recognize the legal effectiveness of future technological developments as they emerge (H. Shahrami, 2024). UNCITRAL adopted this principle to ensure that commercial law remains stable and adaptable despite the rapid pace of technological innovation.

Complementing this approach is the principle of functional equivalence, which provides that where a new technological mechanism performs substantially the same legal function as its traditional counterpart, it should be accorded equivalent legal recognition and effect (Pourmehri, 2025). In the context of public blockchain networks, these two principles operate in conjunction to redefine conventional approaches to the enforcement of judicial judgments.

Under traditional commercial law, negotiable instruments such as bills of exchange or cheques derive their legal significance from physical possession. Blockchain technology, by contrast, enables digital assets

to be transferred electronically through cryptographic authentication and the control of private keys. Applying the principle of functional equivalence, UNCITRAL recognizes that legal control over a digital asset constitutes the functional equivalent of possession of tangible property. Consequently, judicial decisions affecting digital control should enjoy the same legal authority and enforceability as judgments involving conventional property rights (Kariminezhad, 2024). Nevertheless, implementing these principles within modern legal systems presents significant challenges. Technology neutrality may occasionally generate legal uncertainty by intentionally avoiding detailed technological specifications, thereby permitting divergent judicial interpretations. Likewise, functional equivalence becomes increasingly difficult to apply where emerging technologies possess characteristics without meaningful analogues in traditional legal systems. Blockchain's defining features—including immutability, decentralization, and consensus-based validation—lack direct counterparts within conventional commercial law, thereby complicating the application of existing enforcement doctrines (Ahmadi, 2025).

UNCITRAL has attempted to address these challenges through the development of model legislative instruments that preserve broad legal principles while providing sufficient technical guidance to facilitate practical implementation. This legislative strategy reflects UNCITRAL's broader objective of establishing a common legal vocabulary capable of bridging the divide between technological realities and legal requirements.

Recent UNCITRAL instruments further emphasize the legal recognition of digital assets as property capable of judicial attachment, a development directly consistent with the principle of functional equivalence. Contemporary legal scholarship suggests that adoption of these principles within national legal systems, particularly within Iran, could substantially alleviate existing obstacles to the enforcement of judicial judgments involving blockchain-based assets. Such reform, however, requires significant amendments to existing legislation and the formal recognition of digital control as the legal equivalent of physical possession (Rezaei, 2024).

Ultimately, these foundational principles demonstrate UNCITRAL's commitment to developing a dynamic and technology-compatible legal framework capable of preserving legal certainty and ensuring the enforceability of judicial decisions within the digital economy without becoming dependent upon any particular technological architecture. This approach provides a valuable legislative model for national legal systems confronting the regulatory challenges posed by blockchain technology and underscores the necessity of transitioning from traditional formalistic concepts toward a function-oriented legal methodology.

3.2. Analysis of the UNCITRAL Model Law on Electronic Transferable Records and Its Compatibility with Public Blockchain Networks

The UNCITRAL Model Law on Electronic Transferable Records (MLETR), adopted in 2017, represents one of the most significant international legislative initiatives aimed at harmonizing domestic legal systems with rapidly evolving digital technologies. Its principal objective is to establish a legal framework governing the recognition, transfer, and enforcement of rights embodied in electronically generated transferable records, particularly those operating within distributed ledger technologies such as blockchain.

A defining innovation of the Model Law is its replacement of the traditional legal requirement of physical possession with the concept of control, thereby fundamentally transforming conventional understandings of ownership and asset transfer. Under traditional commercial law, the legal validity of negotiable instruments—including bills of exchange and cheques—depends upon physical possession of the underlying document. Blockchain-based assets, however, exist solely as digital tokens or electronic records and therefore possess no tangible form.

The MLETR provides that a person exercises control over an electronic transferable record where that person is able, either individually or jointly with others, to exercise exclusive authority over the record or to prevent unauthorized use by third parties (Sadeghi, 2022). This definition corresponds closely with the operational architecture of public blockchain systems, in which exclusive possession of a private cryptographic key effectively confers legal and practical control over the corresponding digital asset.

Despite this conceptual compatibility, the application of the MLETR to public blockchain networks presents

several significant challenges. Public blockchains operate through decentralized consensus mechanisms without any central authority capable of modifying, freezing, or correcting entries recorded on the distributed ledger. Consequently, judicial authorities cannot directly implement court orders requiring alteration of blockchain records unless the relevant parties voluntarily cooperate.

UNCITRAL has therefore acknowledged that effective implementation of the Model Law within public blockchain ecosystems requires supplementary technical mechanisms, including judicial enforcement oracles, governable smart contracts, and comparable technological interfaces capable of translating judicial decisions into executable blockchain instructions (Bagherpour, 2025). Although these intermediary mechanisms may appear inconsistent with the decentralized philosophy underlying blockchain technology, they are increasingly viewed as indispensable for ensuring meaningful legal enforceability.

Within the Iranian legal system, implementation of the MLETR would require substantial amendments to both commercial legislation and civil procedure law in order to recognize digital assets formally and establish legal procedures governing their judicial attachment, transfer, and execution. Contemporary legal scholarship indicates that the current incompatibility between Iranian legislation and the requirements of the MLETR has generated considerable uncertainty concerning the legal status of crypto-assets and the practical enforcement of judgments relating thereto (Nazari, 2024).

From a technological perspective, public blockchain networks possess significant advantages—including transparency, security, and immutability—that make them highly effective platforms for preserving the integrity of electronic records. Their decentralized architecture, however, simultaneously complicates judicial enforcement by eliminating centralized control mechanisms traditionally relied upon by legal authorities.

UNCITRAL therefore encourages states to reduce the disparity between technological realities and legal requirements through coordinated legal reforms accompanied by the development of appropriate technical infrastructure. Ultimately, analysis of the MLETR demonstrates that, although UNCITRAL has established an innovative legal framework by recognizing control as the functional equivalent of possession, its effective application to public blockchain environments continues to depend upon extensive international cooperation and the development of common technical standards capable of translating judicial decisions into instructions executable by decentralized blockchain networks (Maleki, 2024).

Accordingly, successful implementation requires not only legislative reform at the domestic level but also continued technological innovation directed toward designing blockchain architectures capable of accommodating legitimate judicial intervention while preserving the core principles of decentralized governance.

4. Legal and Operational Challenges within the Iranian Legal and Judicial System

An examination of the legal and operational challenges confronting the Iranian legal and judicial system in addressing blockchain technology and digital assets reveals a substantial gap between the rapid evolution of technological innovation and the rigidity of traditional legislative structures. This disparity has created considerable uncertainty for judges and enforcement authorities responsible for implementing judicial decisions involving crypto-assets.

The first and most fundamental challenge concerns the legal characterization of digital assets as property within the framework of the Iranian Civil Judgments Enforcement Act. The Iranian legal system is traditionally founded upon the classical distinction between movable and immovable property and generally requires that property possess an identifiable legal existence and economic value. Pursuant to Article 11 of the Civil Code and the relevant provisions of the Civil Judgments Enforcement Act, property must possess economic value and be capable of ownership. Nevertheless, considerable uncertainty persists as to whether crypto-assets—which lack physical existence and are not issued or guaranteed by any governmental authority—may legally qualify as property subject to judicial attachment and execution (Fallahi, 2024).

Some legal scholars argue that, owing to their intangible nature, crypto-assets more closely resemble personal rights or intangible claims than conventional property. Conversely, the substantial economic value and

extensive commercial use of digital assets strongly support their recognition as property capable of legal protection. However, the Civil Judgments Enforcement Act of 1977 was drafted long before the emergence of blockchain technology and therefore defines property in terms incompatible with the technical characteristics of cryptocurrencies, including cryptographic authentication, decentralization, and the absence of intermediary institutions. As a consequence, in many enforcement proceedings, judgment creditors remain unable to seek judicial attachment of a judgment debtor's digital wallet based upon existing statutory provisions (Khosravi, 2025).

This legislative deficiency becomes particularly evident in Article 20 of the Civil Judgments Enforcement Act, which governs the attachment of movable property held by third parties. Within public blockchain networks, however, no legally identifiable third-party custodian exists upon whom a judicial attachment order may be served. Accordingly, uncertainty concerning the legal characterization of digital assets constitutes the first major obstacle to effective judicial enforcement, allowing substantial blockchain-based wealth to remain beyond the practical reach of existing legal mechanisms (Najafi, 2024).

Even assuming that crypto-assets are formally recognized as property, additional complexities arise concerning the judicial attachment of decentralized assets and the legal responsibilities of cryptocurrency exchange platforms in cooperating with judicial authorities. Within decentralized blockchain systems, control over digital assets depends exclusively upon possession of private cryptographic keys. Where a judgment debtor refuses voluntarily to disclose such keys, neither judges nor enforcement officers possess the technical capability to access the corresponding digital wallet or transfer its contents.

This technological limitation fundamentally conflicts with the traditional doctrine of judicial authority. In relation to conventional property, enforcement officers may exercise coercive state power to seize assets directly. In the digital environment, however, governmental coercion cannot overcome cryptographic security mechanisms designed specifically to prevent unauthorized access (Moradi, 2025).

Within this context, domestic cryptocurrency exchanges represent the principal centralized actors within an otherwise decentralized ecosystem and consequently face increasing pressure to assist judicial enforcement authorities. Their legal responsibilities, however, remain uncertain. To the extent that digital assets remain under the exchange's custodial control, compliance with judicial attachment orders may be feasible. Where users have transferred their assets to privately controlled wallets, however, exchanges can generally provide only historical transaction records and possess no practical ability to freeze or recover the assets themselves (Abbasi, 2024).

Furthermore, the absence of comprehensive regulations governing cooperation between cryptocurrency exchanges, the Cyber Police (FATA), and the Judiciary has generated uncertainty concerning the balance between user privacy obligations and compliance with judicial orders. Many exchanges consequently face the risk of severe regulatory sanctions—including the suspension of banking services—for misconduct attributable to individual users, reflecting the absence of a coherent and technologically informed regulatory framework governing digital asset service providers (Rezaei, 2025).

An additional operational challenge concerns the identification of asset ownership within pseudonymous blockchain networks. The pseudonymous architecture of public blockchains substantially complicates implementation of Article 2 of the Law on the Enforcement of Financial Convictions, which requires identification of the judgment debtor's assets before enforcement may proceed. Effective blockchain asset tracing requires highly specialized technical expertise and sophisticated blockchain forensic tools, neither of which are currently available on a sufficiently widespread basis within Iranian judicial enforcement institutions.

This operational deficiency has resulted in situations where, notwithstanding the issuance of valid judicial attachment orders, enforcement becomes practically impossible because authorities cannot identify the relevant blockchain addresses or because digital assets are rapidly transferred to foreign cryptocurrency exchanges beyond the jurisdictional reach of Iranian courts (Salehi, 2024).

Ultimately, the tension between the decentralized principles governing blockchain technology and the judiciary's institutional need for supervision and control

has evolved into a significant challenge affecting the effectiveness of civil judgment enforcement in Iran. Resolving this challenge requires both comprehensive legislative reform and the development of sophisticated technical infrastructure capable of supporting judicial supervision of digital assets.

Unless the legislature establishes a clear legal relationship between digital control and judicial attachment, blockchain technology may increasingly serve as a mechanism for avoiding financial obligations and frustrating judicial enforcement, thereby undermining public confidence in the administration of justice within the digital economy (Naseri, 2025).

This situation further necessitates that judges, prosecutors, and judicial enforcement officers acquire not only an understanding of the applicable legal doctrines but also practical familiarity with blockchain architecture and distributed ledger technologies. Such expertise would facilitate the development of innovative enforcement mechanisms—including the attachment of custodial exchange accounts or supervised transfers of digital assets under judicial oversight. Nevertheless, absent explicit statutory authorization, these practical solutions remain legally vulnerable to challenge before higher judicial authorities.

Taken together, these challenges demonstrate that the Iranian legal system is presently undergoing a period of significant transition. Comprehensive legislative reform governing digital assets, blockchain technology, and judicial enforcement is therefore indispensable if the legal system is to provide effective protection for victims of digital asset disputes and preserve public confidence in the administration of justice within the emerging digital economy.

5. Comparative Evaluation and the Development of Novel Models for the Convergence of Code and Law

Comparative analysis of leading legal systems and distributed ledger technologies demonstrates that the traditional perception of an inherent conflict between code and law is gradually being replaced by an emerging paradigm commonly described as “law as code.” Initially advanced within the literature of international legal scholarship, this concept has evolved into a practical necessity for public blockchain ecosystems seeking to reconcile the rigidity of algorithmic execution with the flexibility required for the administration of justice (Shakeri, 2025).

Comparative experience indicates that several jurisdictions have adopted a model of technology-oriented regulation under which legal requirements are embedded directly into blockchain protocols. For example, under the European Union’s Markets in Crypto-Assets (MiCA) Regulation, certain regulated service providers are required to implement mechanisms capable of temporarily suspending or reversing transactions under exceptional circumstances. This development reflects a significant conceptual shift: code is no longer regarded as an autonomous and self-governing system but as an infrastructure that must accommodate legally authorized intervention (Nazari, 2024).

For the Iranian legal system, one of the most promising models involves the implementation of judicial oracles. A judicial oracle functions as an interface that converts judicial decisions into machine-readable instructions capable of execution by smart contracts. Under such a framework, once a court issues an order for the attachment or transfer of digital assets, the oracle transmits the relevant judicial information to the blockchain network and, where an appropriate governance layer has been incorporated into the smart contract, automatically implements the required legal consequences (Bagherpour, 2025).

Such integration fundamentally transforms judicial enforcement from a manual and time-consuming process into an automated and near-instantaneous mechanism. Besides preventing judgment debtors from rapidly transferring digital assets beyond the reach of enforcement authorities, this approach substantially reduces enforcement costs and enhances procedural efficiency.

Recent studies further suggest that on-chain arbitration constitutes another important manifestation of the convergence between law and code. Within these decentralized dispute resolution systems, specialized arbitrators resolve disputes directly on the blockchain through token-based governance and voting mechanisms rather than through conventional judicial institutions (Sarvar, 2024).

Nevertheless, the complete substitution of legal rules with computer code remains problematic. Many fundamental legal concepts—including good faith,

reasonableness, equity, and urgency—are inherently interpretative and context-dependent, making their reduction to deterministic computational instructions extremely difficult. Accordingly, an appropriate model for the Iranian legal system should adopt a hybrid architecture whereby the technical execution of judicial decisions is entrusted to blockchain-based code, while interpretative legal judgments remain within the exclusive authority of human judges (Hosseini-Far, 2025).

Under this hybrid framework, code functions primarily as a mechanism ensuring the effective implementation of judicial decisions, whereas judicial discretion remains the ultimate source of legal interpretation and normative legitimacy.

Contemporary governance models likewise emphasize the use of multi-signature wallets, in which one of the required authorization keys is entrusted to a judicial or regulatory authority. Such arrangements enable access to digital assets, when legally authorized, without requiring the cooperation of the judgment debtor (Salehi-Nia, 2024). Although this approach inevitably raises concerns regarding privacy and individual autonomy, it is increasingly regarded as a proportionate mechanism for combating financial crime, fraud, and tax evasion.

Ultimately, the convergence of code and law reflects recognition of a fundamental reality of the digital age: legislative provisions lacking effective technical enforcement mechanisms gradually lose practical authority, while algorithmic systems operating without legal legitimacy risk becoming instruments of technological absolutism.

Accordingly, the preferred regulatory model requires that legal standards be incorporated into blockchain systems by design, an approach commonly described as "law by design." Integrating legal requirements into blockchain architecture during the design phase substantially reduces subsequent conflicts between judicial orders and technological constraints (Jafari, 2025).

Such a proactive regulatory strategy enables blockchain technology to evolve from a perceived threat to the rule of law into a mechanism promoting judicial transparency, legal certainty, and institutional efficiency. Achieving this objective within Iran will require the emergence of legal professionals possessing technological expertise, together with software engineers familiar with legal doctrine, thereby creating a shared interdisciplinary language capable of bridging law and distributed ledger technology. Comparative evaluations therefore suggest that successful governance of blockchain technology requires abandoning one-dimensional regulatory approaches in favor of multi-layered governance models, within which law and code operate not as competing systems but as complementary instruments serving the common objective of ensuring justice and protecting the public interest within an increasingly borderless digital environment.

5.1. Comparative Analysis of the Gap Between UNCITRAL International Standards and Current Iranian Judicial Practice

A comparative assessment of the international standards developed by UNCITRAL and the current judicial practice of Iran reveals a significant divergence in the recognition of the fundamental legal concepts governing digital commerce. This divergence originates primarily from differing conceptions regarding the nature of property and the legal criteria for establishing dominion over digital assets. Through the Model Law on Electronic Transferable Records (MLETR), UNCITRAL departs from traditional formalism by replacing the requirement of physical possession with the concept of control, thereby accommodating the inherently intangible character of blockchain-based assets. By contrast, Iranian judicial practice continues to rely principally upon the Civil Code and the Civil Judgments Enforcement Act, under which property is generally conceived as either tangible property or rights capable of classification within conventional legal categories (Abbasi, 2024).

This conceptual disparity has created significant practical difficulties for Iranian courts in ordering the attachment of digital assets, since cryptocurrencies have not yet been expressly recognized within the principal procedural statutes as property subject to judicial execution.

Whereas UNCITRAL consistently adheres to the principle of technology neutrality, Iranian judicial practice has generally adopted a reactive and technology-specific approach toward public blockchain networks, resulting in inconsistent judicial decisions

across different courts and judicial divisions (Naseri, 2025).

A second area of divergence concerns the principle of functional equivalence. UNCITRAL maintains that electronic records should possess legal validity equivalent to that of traditional paper-based documents. Within Iranian judicial practice, however, the absence of a comprehensive nationwide digital-signature infrastructure and the limited recognition of distributed-ledger records as admissible evidence in commercial litigation significantly diminish the evidentiary value attributed to blockchain transactions when compared with official documentary evidence (Sadeghi, 2022). Consequently, parties frequently encounter considerable evidentiary difficulties in establishing ownership of blockchain-based assets before Iranian courts. Further disparities arise in relation to the cross-border enforcement of judicial decisions. UNCITRAL's legal instruments emphasize international judicial cooperation and the mutual recognition of electronically generated legal acts. Iranian judicial practice, by contrast, remains firmly grounded in the territorial principle of jurisdiction and is further constrained by Iran's non-participation in numerous relevant international conventions. As a result, Iranian courts possess only limited practical capacity to enforce judgments against digital assets maintained within foreign blockchain nodes or non-custodial wallets beyond national jurisdiction (Partoo, 2024). This operational limitation stands in marked contrast to UNCITRAL's objective of establishing a secure, predictable, and internationally harmonized commercial environment. From a broader jurisprudential perspective, this divergence reflects differing regulatory priorities. International standards developed by UNCITRAL primarily emphasize facilitating international commerce and ensuring efficient enforcement mechanisms. Iranian judicial practice, on the other hand, has traditionally prioritized the protection of public order and the prevention of capital flight, resulting in comparatively restrictive and inflexible approaches toward emerging financial technologies (Naseri, 2025). Bridging this divide requires the Iranian Judiciary to draw upon contemporary UNCITRAL instruments by issuing specialized judicial directives recognizing control of a private cryptographic key as a rebuttable presumption of ownership and lawful possession. Absent such harmonization, the Iranian judicial system is likely to encounter increasing difficulty not only in resolving domestic disputes involving digital assets but also in participating effectively within international commercial relationships that are progressively migrating toward blockchain-based infrastructures. Comparative analysis further demonstrates that, unless the traditional concepts embodied within Iranian commercial legislation and the Civil Judgments Enforcement Act are revised in accordance with the principle of functional equivalence, the existing gap between domestic judicial practice and international legal standards will continue to widen. This divergence not only impedes the effective administration of justice in disputes involving cryptocurrency fraud and digital asset recovery but also significantly undermines investor confidence and legal certainty within emerging technology sectors.

6. Discussion

An examination of the legal and technical challenges associated with public blockchain networks demonstrates that legal systems worldwide, and particularly the Iranian legal system, are confronting a fundamentally new paradigm that challenges traditional concepts of property, possession, and the enforcement of judicial decisions. The findings of this study indicate that, although UNCITRAL's functional equivalence approach represents a significant advancement toward recognizing the legal validity of digital assets, it encounters substantial technical limitations when applied to the decentralized architecture of public blockchains. These limitations cannot be resolved solely through conventional legal instruments. Fundamentally, public blockchain networks transfer the power of enforcement from sovereign state institutions to mathematical protocols, thereby challenging traditional conceptions of judicial authority.

The analysis further demonstrates that UNCITRAL's recognition of control as the functional equivalent of physical possession enhances legal certainty in digital transactions but simultaneously creates significant practical obstacles during the enforcement stage. Specifically, a court order directing the attachment of crypto-assets cannot be effectively implemented where judicial authorities lack access to the judgment debtor's private cryptographic keys. Within the Iranian legal

system, this technical obstacle is compounded by structural deficiencies in the Civil Judgments Enforcement Act. The legal analysis revealed that the absence of a comprehensive statutory definition of virtual assets has resulted in judicial reluctance to recognize cryptocurrencies as property subject to attachment, thereby undermining creditors' rights and facilitating the concealment of assets within decentralized digital environments.

Comparative analysis further indicates that the divergence between international standards and current Iranian judicial practice extends beyond theoretical differences and encompasses the practical mechanisms of judicial enforcement themselves (Bagheri, 2024).

To address this gap, the study proposes the convergence of code and law as an innovative regulatory model under which judicial procedures become integrated with blockchain architecture. Such convergence requires the judiciary to move beyond a passive regulatory posture by employing mechanisms such as judicial oracles and governance layers embedded within smart contracts, thereby reconstructing judicial enforcement authority within decentralized digital environments. Another significant issue concerns the legal responsibilities of cryptocurrency exchanges, which function as centralized intermediaries within otherwise decentralized ecosystems. Although these platforms may effectively cooperate with judicial authorities, imposing excessive regulatory burdens upon them without adequate statutory safeguards may encourage users to transfer their assets to foreign exchanges beyond the practical reach of domestic regulators (Rezaei, 2025). Consequently, regulatory policy should seek to preserve the rule of law while simultaneously maintaining the competitiveness and dynamism of the digital economy. Ultimately, effective enforcement of civil judgments involving blockchain technology requires a comprehensive transformation of both evidentiary rules and judicial enforcement procedures. Iranian judges should be equipped with blockchain forensic tools and chain-analysis technologies, while the legislature should draw inspiration from UNCITRAL's model instruments to establish a dedicated statutory framework governing digital assets within commercial law and judgment-enforcement legislation (Radmanesh, 2024).

The findings therefore emphasize that blockchain should not be regarded as a legal vacuum beyond the reach of judicial authority but rather as a new jurisdictional environment requiring specialized legal rules and enforcement mechanisms. The convergence of code and law ultimately seeks to achieve an appropriate balance between individual autonomy within decentralized systems and the legitimate requirements of public order. Such equilibrium can be realized only through sustained collaboration between legal scholars and software engineers in designing integrated legal-technological systems capable of implementing judicial decisions automatically or semi-automatically. Although blockchain technology undoubtedly presents unprecedented challenges to traditional judicial institutions, it simultaneously offers significant opportunities to enhance transparency, efficiency, and legal certainty in judicial enforcement. Realizing these opportunities requires abandoning purely traditional legal approaches in favor of embracing technological innovation within the framework of the rule of law (Shakeri, 2025).

Accordingly, improving the technical expertise of judicial personnel and adopting detailed regulatory frameworks governing cooperation between enforcement authorities and digital asset service providers constitute urgent priorities capable of reducing the existing regulatory gap and restoring confidence within the digital economy. Ultimately, Iran's regulatory strategy should evolve beyond policies based solely upon prohibition or non-recognition toward a model of proactive regulation aligned with internationally accepted standards, thereby enabling the country to harness the economic potential of blockchain technology while preserving legal certainty and judicial effectiveness.

7. Conclusion

The interaction between legal systems and blockchain technology, particularly in relation to decentralized public blockchain networks, represents one of the most complex legal challenges of the twenty-first century and renders the transition from traditional legal paradigms to technology-oriented regulatory approaches increasingly unavoidable. The findings derived from the analysis of UNCITRAL instruments, the examination of existing obstacles within the Iranian judicial system, and the evaluation of models promoting the convergence of code and law demonstrate that legal certainty in the digital era can be achieved only where judicial

institutions successfully adapt to the technological realities of distributed ledger technologies. Within this context, the principles of technology neutrality and functional equivalence, developed by UNCITRAL, provide an effective theoretical framework for recognizing digital assets as property capable of judicial attachment. Nevertheless, these principles alone are insufficient to resolve the practical challenges associated with enforcement. The present study demonstrates that the incompatibility between existing Iranian legislation and the technological characteristics of blockchain has generated significant regulatory gaps, particularly because traditional concepts such as physical possession and tangible ownership cannot readily be extended to decentralized and intangible digital assets.

As a consequence, judicial enforcement authorities frequently encounter insurmountable practical obstacles when attempting to seize digital assets whose control depends exclusively upon unique private cryptographic keys. This deficiency not only impedes effective judgment enforcement but also facilitates asset concealment, fraudulent transfers, and the evasion of financial obligations.

One of the principal contributions of this research lies in demonstrating the necessity of moving beyond reactive legal responses toward proactive strategies integrating law and technology. The study concludes that the most effective long-term solution is the development of meaningful convergence between code and law, whereby legal requirements are incorporated directly into the technological infrastructure of blockchain systems, enabling judicial decisions to be executed automatically or semi-automatically whenever legally authorized.

Mechanisms such as judicial oracles, governable smart contracts, and multi-signature wallets operating under judicial supervision have the potential to bridge the gap between legal authority and technological implementation. Within such a framework, code no longer functions merely as a communication protocol but becomes an instrument for implementing legally authorized judicial decisions while deriving its legitimacy from the legal system itself.

Achieving this objective, however, requires comprehensive structural reform of commercial legislation, civil procedure, and enforcement law so that digital assets are recognized not as exceptional or peripheral phenomena but as integral components of the legal system governing property capable of judicial attachment and execution.

The comparative analysis further demonstrates that the existing divergence between UNCITRAL standards and Iranian judicial practice is attributable both to the relatively slow adoption of contemporary legal concepts and to the absence of the technical infrastructure required within the Iranian judiciary. Bridging this divide requires a comprehensive national strategy involving specialized legal education in technology law, the development of blockchain forensic capabilities, and the implementation of advanced chain-analysis tools enabling enforcement authorities to trace digital assets across decentralized networks. Likewise, the legal responsibilities of domestic cryptocurrency exchanges should be clearly defined in a manner that facilitates cooperation with judicial authorities without imposing disproportionate regulatory burdens capable of encouraging capital migration toward foreign platforms.

Ultimately, the successful enforcement of judicial judgments within blockchain environments requires a multidisciplinary approach involving legal scholars, software engineers, blockchain architects, judges, and enforcement authorities working collaboratively to design legal-technological systems capable of preserving both the rule of law and the decentralized characteristics of blockchain technology. Failure to embrace this convergence would effectively require judicial systems to accept persistent enforcement failures in addressing emerging forms of digital economic misconduct. Conversely, the transition toward a digitally integrated legal order—within which law and code operate in mutual complementarity—offers the most practical means of safeguarding investment security, enhancing judicial effectiveness, and preserving legal certainty within the digital economy. Although this transformation will undoubtedly involve significant legislative, institutional, and technological challenges, it constitutes a strategic necessity for maintaining Iran's competitiveness within international commercial relations and for reducing systemic vulnerabilities arising from rapidly evolving digital technologies.

Authors' Contributions

Authors contributed equally to this article.

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