Legal Transformation of Contracting Agreements in the Digital Age: An Analysis of the Role of Artificial Intelligence in Ensuring Transparency and Reducing Legal Risks in Contracts

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Abstract

The digital transformation of recent decades, particularly with the emergence and expansion of novel technologies such as artificial intelligence, has laid the groundwork for a profound shift in contractual systems, including contracting agreements. Contracts that were previously grounded primarily in traditional legal principles and models based on written and human-based agreements are now encountering new concepts such as analytical algorithms, smart contracts, and legal conflict prediction systems. This study, employing a descriptive–analytical approach and based on library research and an examination of valid domestic and international legal documents and scholarly articles, investigates the role of artificial intelligence technologies in enhancing the transparency of contracting agreements and reducing legal risks resulting from ambiguity, delays, or breaches in the performance of obligations. The findings indicate that artificial intelligence tools—such as natural language processing (NLP), machine learning, and risk analysis algorithms—can help prevent legal disputes at various stages of contractual execution by identifying ambiguous clauses, forecasting potential conflict points, and offering corrective recommendations. Additionally, the use of blockchain-based smart contracts enables the automatic execution of obligations upon the fulfillment of predetermined conditions. The study concludes that the purposeful and intelligent use of modern digital capabilities necessitates a revision of traditional laws, the development of supplementary regulations, and the design of legal technological infrastructures in order to enable the efficient deployment of artificial intelligence in the management and execution of contracting agreements.

Keywords: Contracting agreements, Artificial intelligence, Digital transformation, Smart contracts, Legal transparency, Contractual risks, Emerging legal technologies

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1. Introduction

In today's world, the expansion of emerging technologies—particularly in the field of artificial intelligence—has posed an unprecedented challenge to traditional legal structures. Among the most impacted are construction contracts, which are widely used in both civil and commercial sectors and are now in urgent need of revision and adaptation to the digital era. The increasing

complexity of construction projects, the diversity of technical, financial, and operational elements, and the potential for disputes arising from ambiguity or incomplete execution of obligations have intensified the necessity of employing intelligent tools to mitigate legal risks (Bagheri, 2021; S. Kazemipour, 2022). In this regard, artificial intelligence (AI), with its capabilities such as big data analytics, natural language processing (NLP), and machine learning, has emerged as an effective instrument for the analysis, refinement, and more precise execution of contracts. Studies demonstrate that AI can play a significant role in minimizing disputes and ensuring proper enforcement of construction contracts by identifying ambiguous clauses, evaluating legal risks, predicting potential conflicts, and offering corrective recommendations (Ashley, 2017; Susskind, 2020). In Iran, although certain regulations relating to electronic commerce and digital signatures represent initial steps toward accepting technological tools in the realm of contracts, the legal infrastructure for employing AI in drafting, managing, and executing construction contracts remains undeveloped (Asadi et al., 2022; Mohseni, 2021). Therefore, a legal analysis of AI's role in this domain can greatly contribute to identifying its potentials, clarifying existing legal gaps, and proposing reforms or legislation. The central objective of this study is to examine the conceptual and structural transformation of construction contracts, with a particular focus on the role of AI technologies in enhancing transparency, predictability, and reducing legal risks.

Hence, the research question emerging in this context is as follows:

Research Question: How can artificial intelligence contribute to the legal transformation of construction contracts in the digital age by ensuring transparency and reducing legal risks?

Research Hypothesis: Artificial intelligence, through data analysis tools, smart contracts, and automated monitoring, can enhance the transparency of construction contracts and reduce legal risks resulting from ambiguities, human errors, and non-compliance with laws.

Regarding the significance of this research, it should be emphasized that the digital transformation in the construction industry—especially through the advent of AI technologies—offers new opportunities for improving the efficiency and transparency of contracts. Due to their technical and legal complexities, construction contracts often face challenges such as contractual disputes, delays in execution, and breaches of obligations. AI can help reduce these issues by automating the processes of drafting, supervision, and execution. By investigating the role of AI in this area, the present study aims to enhance the legal and economic performance of construction projects and propose solutions to reduce legal disputes and increase mutual trust between parties.

In comparison with previous studies, two notable pieces of research can be mentioned:

In a study by Safari et al. (2023), the role of blockchain-based smart contracts and AI in increasing the transparency of construction contracts was examined. The findings indicated that smart contracts, by automating the execution of obligations and recording transactions in a decentralized manner, can reduce ambiguities and legal disputes (Safari et al., 2023). This study also emphasized the importance of AI in the automated analysis of contractual conditions and the identification of inconsistencies. Additionally, a study by Mohammadi and Rezaei (2024) explored the use of AI in analyzing the legal risks of construction contracts. It demonstrated that machine learning-based AI tools can detect high-risk clauses in contracts and offer suggestions for their modification. These tools, by analyzing historical litigation data, are capable of recognizing risk patterns and contributing to a reduction in litigation-related costs (Bagheri, 2021; S. Kazemipour, 2022).

2. Theoretical Framework of the Research

2.1. Definition and Status of Construction Contracts in the Legal System

Construction contracts are among the most significant contract types in the legal systems of Iran and many other countries, especially in large-scale national infrastructure projects such as road construction, dam building, refinery construction, technological ventures, and public or government construction initiatives. Legally, these contracts often represent a hybrid structure combining personal service leases, obligation-to-result clauses, and in some cases, joint construction agreements. Due to their inherent complexity and the multi-stakeholder involvement, construction contracts are highly prone to legal disputes, risks arising from incomplete performance of obligations, project delays, or misinterpretation of contractual clauses (Mahdavi,

2017). Within this framework, the need for tools that can ensure transparency and coherence throughout the drafting, implementation, and even dispute resolution phases of a contract is felt more than ever.

2.2. Conceptual Transformation of Contracts in the Digital Age

The advent of digital technologies—particularly artificial intelligence—has brought about fundamental changes to traditional concepts of contracts and their enforcement. Traditionally, a contract was a written agreement between two or more natural or legal persons, based on which specific obligations were defined under human oversight. However, in the digital age—especially with the emergence of data-driven systems, machine learning, and predictive algorithms—the contract has become a dynamic, analyzable, and even self-executing process (Surden, 2012; Susskind, 2020). While these changes open new horizons, they simultaneously introduce challenges in terms of legal validity, admissibility, and accountability for breaches.

2.3. Smart Contracts and the Impact of Artificial Intelligence

The concept of the smart contract is a novel development in contract law theory, initially introduced by Nick Szabo, and refers to contracts whose terms are encoded in digital form and executed on blockchain platforms (Szabo, 1997). In construction contracts, smart contracts can manage processes such as automatic payment upon completion of work stages, activation of delay penalties, and phased delivery of the project based on predefined data inputs. However, challenges persist regarding the inability to predict and code all contractual conditions, ambiguity surrounding the parties' intent, and the mechanisms for legal oversight and enforcement (Tapscott & Tapscott, 2016).

3. Legal Status of Smart Contracts in the Iranian Legal System with Emphasis on Public and Private Construction Projects

Artificial intelligence can play an integral role at various stages of the contract lifecycle through technologies like natural language processing, legal data mining, and recommender systems. These tools assist in drafting contracts based on prior templates, analyzing risks, identifying ambiguous clauses, predicting the likelihood of non-compliance, and recommending revisions. By leveraging judicial and legal databases, these technologies identify patterns in past breaches or disputes and offer recommendations grounded in statistical analysis (Chesney & Citron, 2019). In construction projects, where the volume of documents, annexes, and information exchange is high, AI can significantly enhance the speed and accuracy of contract management by reducing reliance on human input (Asadi et al., 2022).

The entry of new technologies, particularly blockchain-based systems, has introduced the innovative concept of the smart contract into legal discourse. While such contracts initially seem to offer transformative benefits by reducing transaction costs, ensuring transparency, and eliminating traditional intermediaries, in legal systems grounded in traditional frameworks like Iran's, various questions arise about their nature, validity, and legal implications (Yazdani, 2021). In the Iranian legal system, the validity of contracts is primarily based on the principle of the autonomy of will and Article 10 of the Civil Code, which holds that contracts not explicitly contrary to law are binding and valid. However, in the case of smart contracts, the critical element of "express and declared intent"—a cornerstone of many civil and Islamic legal institutions—becomes obscured by algorithms and digital code. Consequently, uncertainties emerge around establishing mutual consent, the formation of offer and acceptance, and even the interpretability of such contracts (Nikzad & Sadiq, 2023).

Moreover, the automated execution of smart contracts presents challenges for legal institutions such as termination, annulment, and modification—key tools in maintaining contractual equilibrium within Iranian law (Mohseni & Arshadi, 2022). In the domain of construction contracts, these challenges become even more pronounced. Public sector contracts are governed by specific regulations such as the Law on Governmental Tenders, Government Procurement Regulations, and executive directives from the Planning and Budget Organization. These rules impose requirements including adherence to tender procedures, administrative transparency, reporting to oversight bodies, and human supervision. The use of smart

contracts in this domain has met with both technical and legal resistance, as their unmediated execution can neutralize oversight and financial auditing mechanisms (Beigi & Abadi, 2020).

By contrast, in the private sector—where there is broader contractual freedom—there is greater potential for implementing smart contracts, provided that fundamental legal principles such as capacity, consent, and legality of the subject matter are observed (Nouruzi & Fallah, 2019). Additionally, the self-executing nature of these contracts may reduce legal risks and deter non-compliance or delays by the parties. Nevertheless, due to the inflexibility of this technology, automatic enforcement of obligations under conditions such as force majeure, economic crises, or market fluctuations may lead to unjust outcomes. As a result, many Iranian legal scholars argue that the implementation of smart contracts should occur within a hybrid legal framework that allows for human oversight—thereby harnessing the advantages of technology while avoiding legal rigidity (Mansouri, 2021).

4. Analysis of the Role of Artificial Intelligence in the Transformation of Construction Contracts

4.1. Functions of Artificial Intelligence in Drafting and Analyzing Construction Contracts

AI can play a significant role in the drafting and legal review of construction contracts by standardizing formats, reducing human error, and predicting legal risks. Machine learning-based intelligent systems, through analysis of past contracts, identification of conflict patterns, and examination of judicial and arbitral precedents, are capable of extracting high-risk clauses and suggesting alternatives. These capabilities are particularly beneficial in large engineering, procurement, and construction (EPC) contracts characterized by high complexity and diversity, thereby enhancing the efficiency and transparency of legal relationships (Surden, 2014).

In Iran, researchers argue that the lack of a unified model for drafting construction contracts has contributed to an increase in contractual disputes, and the adoption of intelligent technologies can serve as a complementary tool for establishing legal order (Bagheri, 2021).

4.2. Intelligent Supervision of Contractual Performance in Construction Projects

Another transformative function of AI in the construction sector lies in supervising the proper execution of contractual obligations. In large-scale infrastructure and industrial projects—typically involving multiple contractors and subcontractors—traditional oversight requires extensive human resources, repeated reporting, and continuous field inspections. AI-based systems can monitor real-time data on material usage, physical progress, equipment status, and even workforce behavior to assess performance quality accurately (Tapscott & Tapscott, 2016).

Although Iran's legal framework does not explicitly provide for the use of such technologies in supervisory roles, general principles of obligation performance, the binding nature of contracts, and Article 220 of the Civil Code may be interpreted to support the inclusion of intelligent tools as implied contractual terms—provided the parties explicitly agree in the contract on the use of monitoring technologies (Safaei, 2021).

4.3. The Role of Artificial Intelligence in Predicting Disputes and Reducing Legal Risks

One of the most significant contributions of artificial intelligence to construction contracts is its ability to predict conflict points and manage legal risks before disputes arise. Predictive analytics systems, by analyzing millions of documents, court decisions, arbitration practices, and contractual records, can provide probabilistic warnings regarding potential breaches, delays, or disputes. For instance, algorithms developed by LexPredict use historical data from failed contracts to determine the likelihood of dispute for each specific contractual clause (Casey & Niblett, 2016). This capability enables employers and contractors to proactively modify terms or include alternative dispute resolution mechanisms to avoid costly litigation. In Iran's legal system, judicial precedents reveal that a substantial number of contractual disputes stem from varying interpretations of clauses—many of which could have been avoided through precise predictive analysis (Safari et al., 2023). The use of intelligent tools in this context shifts the focus from reactive litigation to proactive legal prevention.

4.4. Legal Constraints and Considerations in Using Artificial Intelligence

Despite the promising advantages of AI in transforming construction contracts, several legal barriers and considerations persist.

First is the issue of algorithmic transparency. Many of the algorithms employed in contract analysis are based on deep learning, whose decision-making processes are opaque and irreproducible. From a legal perspective, this lack of transparency can violate principles such as clarity, the right to defense, and contractual equality (Burrell, 2016).

Second, the issue of legal liability in the event of errors or malfunction by AI systems remains ambiguous in most legal frameworks, including Iran. If a smart system makes a mistake in analyzing a contract and causes damage to one party, it is unclear who bears responsibility for compensation—the developer, the user, or the system itself.

Third, the lack of alignment between Iranian law and emerging technologies, particularly regarding digital signatures, digital identity, and the validity of non-written contracts, presents a structural challenge for the implementation of AI-based legal tools. Iranian legal scholars believe reforms in civil, commercial, and procedural codes are essential to allow the legitimate and secure application of AI in drafting and executing contracts (E. Kazemipour, 2022).

5. The Role of Smart Contracts in Redefining the Notion of "Free Will" in Private Law

In the Iranian legal tradition, similar to many civil law systems, the principle of freedom of will in contract formation is fundamental and protected. This principle entails that parties enter into legal commitments consciously and voluntarily (Katouzian, 2013). However, the introduction of technologies such as smart contracts has shifted many contractual decisions—especially those related to terms, execution, and even termination—into the hands of algorithms, whether designed by developers or refined through machine learning. As a result, it is increasingly difficult to assert that human intent is present in all stages of the contract or that such intent is expressed with full awareness and clarity.

The essential concern is that smart contracts—unlike traditional contracts that rely on human dialogue, interpretation, and negotiation—are executed through code and operate automatically once a condition is met, without requiring renewed consent. For example, if a contractor agrees that payment will be made automatically from the employer's digital wallet upon equipment delivery by a certain date, that transaction will occur instantly when the condition is met, even if both parties later wish to delay it. This self-executing logic threatens the traditional flexibility of will and the right to renegotiate execution terms (Werbach & Cornell, 2017). Such developments demand a serious reevaluation of the classical consensus-based theory of contract formation.

While Iranian law has not explicitly addressed smart contracts, their legitimacy may be inferred from general contract principles and Article 10 of the Civil Code, which is grounded in the freedom of contract, provided that genuine and informed intent, free of coercion or mistake, is evident at the time the contract data is entered into the system (Safaei, 2021). From this perspective, the emergence of smart contracts—particularly those involving adaptive AI—destabilizes the core notion of free will in contract law and necessitates a thorough reexamination of traditional contract doctrines. In Iran's legal system, where concepts such as consent, intention to create legal relations, and mutual agreement are fundamental to contract validity, legislators and legal scholars must explicitly define the boundaries of technological intervention in contract formation and enforcement to prevent the proliferation of "contracts without will."

6. Digital Arbitration and Algorithmic Mediation in Smart Contracts

The digital transformation of contract law—especially in the realm of construction contracts—has led to the rise of innovative dispute resolution mechanisms. One of the most notable developments is digital arbitration and the use of algorithmic mediators. In this model, AI-equipped systems draw on contractual data, transaction histories, and behavioral analytics to act as mediators or even private judges. This is particularly relevant for smart contracts executed on blockchain platforms, where arbitration clauses and dispute resolution protocols are often pre-coded into the contract itself (Werbach & Cornell, 2017).

The legitimacy and validity of such arbitration remains one of the major challenges in classical legal systems. Under current Iranian law, arbitration requires the informed consent of the parties, and the arbitrator must be a legally recognized entity subject to accountability. However, in algorithmic arbitration, parties may be unaware of how arbitration is conducted at the time of signing a digital contract, and the algorithmic arbitrator lacks legal personality, supervision, and accountability mechanisms. According to research by Mousavi Bejnordi (2022), arbitration must meet three essential conditions—independence, impartiality, and credibility—all of which are seriously challenged in the context of learning algorithms (Mousavi Bejnordi, 2022).

As a result, some researchers have proposed a hybrid arbitration model, in which the algorithm functions solely as a data processor and analyzer, while the final decision is rendered by a human. For instance, Rezazadeh (2020) argues that smart systems should serve only as machine legal advisors, not as final arbitrators (Rezazadeh, 2020). From a comparative law perspective, countries such as the UK, Canada, and Australia are in the process of developing legal frameworks to regulate the liability of arbitration algorithms (Allen & Widdison, 1996). These jurisdictions stress the importance of decision traceability and have set conditions that require intelligent systems to provide comprehensive reports on the logic, reasoning, and evidence behind each decision.

Therefore, the broad application of digital mediation and algorithmic arbitration in construction contracts requires a major revision of Iran's arbitration regime, reforms to civil procedure laws, and the creation of independent regulatory bodies to monitor the quality of AI-driven decisions. The absence of such legal frameworks may soon result in violations of fundamental citizen rights, undermine judicial fairness, and foster growing distrust in digital legal mechanisms.

7. Ambiguity in Legal Liability Arising from AI Decisions

One of the most critical challenges in using artificial intelligence in contractual processes is the lack of clarity in determining legal liability when errors, damages, or breaches of contract occur due to algorithmic actions. In traditional contracts, liability typically falls on human parties (whether individuals or legal entities). However, in contracts where part of the decision-making, drafting, or execution is delegated to intelligent systems, the key question arises: if the AI output is based on flawed analysis or inaccurate predictions and results in damage to one of the parties, who is responsible? The algorithm developer? The employer deploying the system? Or a third party who configured the system? Western legal literature has introduced concepts such as non-person-centric liability and human-machine shared responsibility, but there is no legal consensus on the issue (Calo & Kerr, 2013).

In Iranian law, traditional civil liability doctrines—such as Article 1 of the Civil Liability Act and Articles 328 and 331 of the Civil Code—require a demonstrable human fault or an identifiable person (natural or legal) to whom the damage is attributable. Artificial intelligence, as an independent agent, is not currently recognized as legally liable under this framework (E. Kazemipour, 2022). This legislative gap not only impedes the adoption of intelligent systems but could also result in suspended contracts or evasion of responsibility during disputes.

Despite efforts such as the 2003 Electronic Commerce Act, which recognized electronic documents and digital signatures, the legal status of smart contracts and their effects remains insufficiently defined in Iranian law. Technically, a smart contract is a series of computer codes that run on a blockchain and execute automatically. Legally, however, it remains debated whether such a system constitutes a binding contract. Under Iranian law, a contract requires intention and consent, legal capacity, a definite subject, and lawful cause. In smart contracts, intention and consent are expressed non-verbally through coding, making it difficult to verify the parties' true intent, especially in the event of a dispute (Safari et al., 2023). Furthermore, in the absence of specific legal provisions on the validity of coded contracts, courts may reject such contracts or view their enforceability with skepticism. Therefore, reforms in civil, commercial, and procedural law are recommended to explicitly recognize digital and smart contracts and establish criteria for their validity, proof, and enforceability (Asadi et al., 2022).

8. Ensuring Transparency and Risk Reduction in Smart Construction Contracts

Transparency is one of the most prominent features of smart contracts, achieved through the decentralized and immutable nature of blockchain technology. Blockchain operates as a distributed ledger where all transactions, contractual terms, and

modifications are publicly accessible to all authorized parties, making data tampering virtually impossible and strengthening trust between parties (Nakamoto, 2008). For instance, in a construction project, all payments, project milestones, and contract amendments can be transparently recorded on the blockchain. This allows all stakeholders to access real-time, accurate data, thereby reducing disputes stemming from misinformation.

A key method for enhancing transparency is the use of open-source smart contract code, which allows contract parties or independent auditors to review the logic of the contract and ensure that there are no hidden errors or unfair provisions (Buterin, 2014). Tools like Etherscan allow users to inspect the deployed smart contract code on the Ethereum blockchain, significantly enhancing transparency. Additionally, data oracles are used to connect smart contracts to real-world information, such as project progress reports, raw material prices, or environmental conditions—improving operational-level transparency. For example, in a civil engineering project, oracles can feed data from IoT sensors into the smart contract to automatically and transparently verify project progress (Chainlink, 2020). This data is made available to all parties in real time, reducing the risk of disputes caused by incorrect or delayed reporting.

Another transparency-enhancing tool is the use of digital signatures and identity verification protocols such as uPort and Civic, which authenticate the identities of contracting parties and prevent impersonation or unauthorized actions (Civic, 2018). In a construction contract, for instance, digital signatures ensure that only authorized parties can approve or modify the terms, thereby enhancing transparency in determining responsibilities and actions.

In sum, combining these methods transforms smart construction contracts into reliable and transparent tools for project management.

8.1. Risk Reduction in Smart Construction Contracts

Mitigating risks in smart construction contracts requires a multifaceted approach that addresses technical, financial, and legal dimensions. One of the core advantages of smart contracts is their automatic execution based on predefined conditions. This significantly minimizes the risk of non-performance by either party, as actions and payments are only triggered when specific criteria are met (Szabo, 1997). For example, in a construction contract, payment to a contractor can be made contingent upon the completion of a specific project phase, such as laying the building foundation. These payments are typically managed via escrow accounts on the blockchain, which release funds only upon confirmation of condition fulfillment. This mechanism reduces the risk of non-payment or erroneous disbursement, thereby reinforcing financial trust between parties.

From a technical standpoint, auditing the smart contract code is essential to avoid vulnerabilities and logic errors. Tools such as MythX and Slither analyze smart contract code and identify potential weaknesses (Myth, 2021). For instance, a coding bug might unintentionally authorize premature payments or block contract execution. Periodic audits by independent experts minimize such risks. Furthermore, the implementation of multi-signature contracts reduces the likelihood of abuse or unilateral decisions. In these contracts, the execution of transactions requires approval from multiple parties, thereby preventing unauthorized actions (Gnosis, 2020). In a construction project, for example, a payment might require signatures from the employer, contractor, and an independent supervisor.

Smart contracts may also incorporate internal dispute resolution mechanisms, such as digital arbitration protocols or intermediary contracts. For example, platforms like Kleros enable decentralized arbitration in which neutral jurors resolve disputes (Kleros, 2020). These mechanisms help avoid prolonged litigation and reduce legal costs. Moreover, the use of blockchain-based insurance protocols like Nexus Mutual helps cover damages resulting from contract failure or code vulnerabilities (Nexus Mutual, 2021). These protocols are especially valuable in large-scale construction projects where technical or human errors can lead to significant financial losses.

Another major challenge involves blockchain scalability. Platforms like Ethereum often face high transaction fees and processing delays. Scalable networks such as Polygon or Ethereum Layer 2 solutions address these concerns by increasing speed and reducing costs (Polygon, 2021). For instance, Polygon facilitates the execution of smart contracts in large-scale construction projects by offering faster processing and lower fees.

Transparency and risk reduction also require adherence to best practices in smart contract design and implementation. Standardization using templates like ERC-20 (for payment tokens) or ERC-721 (for non-fungible assets like property titles)

enhances reliability and compatibility (Entriken et al., 2018). These standards help developers create contracts that are robust and well-tested. Additionally, educating contracting parties about how blockchain and smart contracts work reduces misunderstandings and operational errors. For instance, employers and contractors must understand concepts such as digital signatures, data oracles, and escrow mechanisms to use smart contracts effectively.

Upgradeable smart contract design is also a recognized best practice. These contracts allow modifications or condition updates without requiring a full redeployment (OpenZeppelin, 2021). For instance, if project regulations or legal requirements change, an upgradeable contract can be swiftly adapted. This is particularly beneficial in long-term construction projects, which may face evolving conditions.

Despite the advantages, smart contracts still face legal complexity and scalability constraints. In many jurisdictions, smart contracts are not yet fully recognized as legally binding, which complicates their enforceability. A viable solution is the use of hybrid contracts, which combine traditional legal elements with smart contract functionalities (Grigg, 2016). In these models, legal provisions are drafted in a conventional format, while performance mechanisms—such as payment or milestone verification—are managed through smart automation. This ensures that the contract is both legally valid and technologically efficient.

Another critical issue is human error in coding. Even a minor bug can cause severe financial or operational consequences. Addressing this requires hiring experienced developers, utilizing audit tools like MythX and Slither, and conducting extensive testing prior to deployment. Moreover, scalability limitations of platforms like Ethereum can be mitigated using alternative networks such as Polygon or Layer 2 solutions, which help reduce costs and delays (Polygon, 2021).

9. Smart Construction Contracts: Legal Challenges and FIDIC Considerations

Legal issues such as capacity, defects in consent and intent, contract interpretation, ambiguity in expressed will, failure to anticipate contractual terms, and challenges related to automated enforcement—including termination, rescission, and contract modification—create significant barriers to the widespread adoption of smart contracts. These challenges are particularly acute in FIDIC-standard contracts, which are extensively used in civil and infrastructure projects due to their internationally recognized format and standardized legal structure.

Smart construction contracts must be examined in light of these legal complexities and aligned with both Iran's legal system and FIDIC's principles to ensure transparency and reduce legal risks. Aspects such as public procurement regulations, the absence of a legal framework for AI-driven contracting, and inconsistencies in automated enforcement procedures require a careful hybrid approach, combining traditional legal validity with smart contract efficiency.

This section of the study thus focuses on identifying key legal obstacles and proposing practical, adaptable solutions for ensuring legal clarity, enforceability, and technological integration in smart construction contracts, especially when used in conjunction with FIDIC-based project frameworks.

9.1. Legal Capacity, Consent Defects, and Will Defects in Smart Contracts

Legal capacity, defects in consent (such as coercion, mistake, or fraud), and defects in will (such as lack of intent) are among the essential conditions for contract validity in the Iranian legal system (Article 190 of the Civil Code) and many other legal systems. These concepts pose serious challenges in smart contracts because party intention is encoded as software, and once deployed, the contract is often immutable.

Ensuring Transparency in Legal Capacity: To ensure that only eligible parties participate in smart contracts, decentralized identity verification protocols such as Civic can be employed (Civic, 2018). These protocols authenticate the digital identity of contracting parties and prevent participation by those lacking legal capacity (e.g., minors or unauthorized entities). For example, in a construction project, a smart contract may only activate after verifying the legal identity of both employer and contractor, thus improving transparency in identifying authorized participants.

Reducing Risks from Consent and Will Defects: Consent defects such as coercion or error can become problematic in smart contracts due to their immutable nature. For instance, if a contractor mistakenly encodes a condition, rectifying it after deployment may be difficult. A recommended solution is using hybrid contracts, which combine traditional and smart formats

(Grigg, 2016). In such models, legal terms are drafted traditionally to address capacity and consent issues, while operational and financial terms are executed through smart automation. Multi-signature contracts also help ensure informed and voluntary agreement by requiring approval from all involved parties, thus minimizing risks related to coercion or deception (Gnosis, 2020).

FIDIC Alignment: FIDIC contracts often include explicit provisions for verifying party capacity, such as requiring the contractor to provide legal authorizations and licenses. Smart contracts can enforce such provisions using data oracles, which verify credentials via official government databases (Chainlink, 2020).

9.2. Contract Interpretation, Ambiguity in Intention, and Unanticipated Terms

Interpreting smart contracts and clarifying ambiguous intentions are challenging due to their code-based nature. Additionally, unanticipated terms can lead to execution problems, as smart contracts are generally immutable after deployment.

Transparency in Interpretation: To improve clarity, hybrid contracts are again advised, offering readable, human-friendly legal text alongside the smart-coded execution logic (Grigg, 2016). For instance, in a FIDIC-based construction project, payment terms may be encoded, while dispute interpretations are referred back to the traditional agreement. Data oracles (e.g., Chainlink) can also be used to feed real-time project data—such as construction progress—into the contract, reducing ambiguity caused by faulty inputs (Chainlink, 2020).

Mitigating Ambiguity and Gaps: Ambiguity or failure to anticipate future terms may lead to unfair outcomes. To prevent this, smart contracts should be developed using standardized templates like ERC-20 (for payments) or ERC-721 (for unique digital assets) (Entriken et al., 2018). Moreover, upgradeable contract structures can allow for post-deployment adjustments or inclusion of new clauses without requiring full redeployment (OpenZeppelin, 2021). For example, if raw material prices unexpectedly fluctuate, an upgradeable contract can implement price adjustment clauses.

FIDIC Alignment: Due to their standardized structure, FIDIC contracts reduce interpretive ambiguity. For example, the Red Book includes specific clauses for managing variations. Smart contracts can encode these provisions, but must use data oracles to verify triggering conditions (e.g., delays or cost changes).

9.3. Challenges of Automated Execution: Termination, Rescission, and Adjustment

While automated execution in smart contracts enhances transparency and efficiency, it complicates scenarios that require mutual consent or human intervention, such as termination, rescission, or contractual adjustment.

Transparency in Automated Execution: By recording all transactions on the blockchain, smart contracts ensure high transparency in obligation fulfillment (Nakamoto, 2008). For example, in a FIDIC construction contract, payments can be automatically executed upon verification of progress milestones via data oracles.

Mitigating Risks in Termination, Rescission, and Adjustment: Smart contracts typically resist change, making termination or rescission complex. Upgradeable contract designs (e.g., via OpenZeppelin) allow for defined conditions under which a contract may be terminated or altered (OpenZeppelin, 2021). For instance, a contract might be coded to terminate automatically if a project delay exceeds a set threshold. Similarly, decentralized arbitration protocols such as Kleros can mediate disputes arising from such actions (Kleros, 2020). For adjustment clauses, oracles can monitor variables like input costs and dynamically revise payments based on FIDIC adjustment terms.

FIDIC Alignment: FIDIC contracts provide detailed conditions for termination (e.g., Clause 15 in the Red Book) and adjustment (e.g., Clause 13). Smart contracts can execute these automatically but require precise coding and verified data inputs (e.g., delays, cost changes) to avoid legal ambiguity.

9.4. Public Procurement Contracts

In Iran, public construction contracts follow the General Conditions of Contract and directives from the Planning and Budget Organization. Smart contracts face challenges in this area due to regulatory oversight and alignment with domestic law.

Transparency in Public Procurement: Smart contracts can enhance transparency by decentralizing the recording of all transactions and project phases. For example, payments to contractors can be automatically executed only after confirmation by a designated government supervisor, thereby reducing corruption and delays (Nakamoto, 2008).

Risk Reduction: To mitigate legal and procedural risks in public procurement, hybrid contracts can be designed to comply with local laws such as Article 190 of the Civil Code (Grigg, 2016). Additionally, escrow accounts managed on the blockchain can ensure that payments are only released upon verified project milestones (Szabo, 1997). For instance, in a government-funded infrastructure project, the smart contract can link fund release to milestone confirmation by a government inspector.

FIDIC Alignment: FIDIC contracts are frequently used in internationally funded public projects. They offer a flexible framework for project governance. Smart contracts can be programmed to execute FIDIC provisions—such as dispute resolution or variation management—but must be harmonized with local regulations to ensure legal enforceability.

9.5. Absence of Legal Frameworks and AI Legislation

The lack of clear legal frameworks governing smart contracts and artificial intelligence is a major barrier in construction contracting, especially in projects inspired by FIDIC-based standards.

Transparency through Legal Hybridity: Hybrid contracts that combine traditional legal clauses with automated execution can offer a pathway toward transparency even in the absence of formal regulatory structures (Grigg, 2016). For instance, legal terms may be drafted in accordance with Iranian civil law, while financial execution is handled through a smart contract mechanism.

Risk Mitigation: In the absence of specific legislation, tools like decentralized arbitration protocols (e.g., Kleros) can assist in dispute resolution (Kleros, 2020). Additionally, blockchain-based insurance protocols such as Nexus Mutual can help cover damages arising from smart contract malfunctions or AI-related errors (Nexus Mutual, 2021). For example, if an AI misinterprets project data, insurance can compensate for the resulting losses.

FIDIC and AI Integration: FIDIC contracts offer a standardized model that can be adapted to smart contract structures. However, the use of AI for analysis or execution (e.g., risk prediction or performance monitoring) requires a comprehensive legal framework—one that has yet to be fully developed in Iran and in many jurisdictions worldwide.

9.6. Integration with FIDIC Contracts

FIDIC contracts—such as the Red, Yellow, and Silver Books—are widely applied in international and domestic infrastructure projects due to their standardization and flexibility. Integrating smart contracts with FIDIC standards involves several dimensions:

Transparency: Smart contracts can automate FIDIC provisions, such as milestone payments and change management. For example, Clause 14 of the Red Book governs staged payments and can be implemented using smart escrow accounts.

Risk Mitigation: Code auditing tools like MythX and upgradeable contract architecture (e.g., via OpenZeppelin) can minimize execution errors (Myth, 2021; OpenZeppelin, 2021). Additionally, data oracles (e.g., Chainlink) can validate project progress in real time according to FIDIC benchmarks (Chainlink, 2020).

Challenges: Aligning smart contracts with FIDIC requires precise coding of complex clauses (e.g., for variations and dispute resolution) and harmonization with domestic legal systems. In Iran, for instance, smart FIDIC contracts must comply with General Conditions of Public Contracts and other national procurement rules.

10. Conclusion

The advent of digital technologies—especially blockchain and artificial intelligence—marks a turning point in the conceptual, structural, and functional transformation of contractual relations, particularly in construction contracting. Smart contracts, underpinned by blockchain and empowered by AI algorithms, offer an innovative mechanism for executing and supervising obligations with minimal human intervention. Their main benefits include reduced administrative costs, faster

performance of obligations, enhanced transparency, and prevention of breaches. However, these advantages come with significant legal and regulatory challenges, particularly within the Iranian legal system.

Iranian contract law, rooted in civil law and Islamic jurisprudence, is based on concepts such as intention, offer, acceptance, termination, adjustment, and judicial interpretation. Smart contracts, which are executed via immutable software code, diverge fundamentally from these traditional principles. This conceptual gap raises concerns about their legal validity, enforceability, and legitimacy in Iran.

In public procurement, especially in government construction contracts, the use of smart contracts faces serious legal, procedural, and regulatory constraints. Current financial and administrative regulations mandate traditional procedures such as tendering, reporting, budget approvals, and human oversight. Without amendments to higher-order legal codes and public sector regulations, the full legal implementation and legitimacy of smart contracts and AI-based execution remain out of reach.

Nonetheless, smart contracts show substantial potential for enhancing transparency and reducing legal risks in construction contracts, especially those aligned with FIDIC standards. Solutions such as identity verification protocols and hybrid contracts address issues of capacity and consent. Upgradeable contracts and decentralized arbitration offer remedies for ambiguity and dispute resolution. For automated enforcement, particularly in termination or adjustment, precise coding and use of oracles are essential. In government contracts, compliance with national laws and the use of escrow accounts are crucial. The lack of AI legislation can be partially managed through hybrid structures and blockchain insurance mechanisms. Full integration with FIDIC standards will require advanced coding, local legal alignment, and deployment of complementary technologies like data oracles.

Proposed Solutions

• **Draft and Enact Specialized Legislation for Smart and Digital Contracts**: The legislature, in coordination with bodies such as the Guardian Council, Judiciary, Planning and Budget Organization, and the Supreme Council of Cyberspace, should develop an independent legal framework for smart contracts and AI's role in contract formation, execution, and monitoring. This framework should address legal intent, proof of consent, interpretability, termination, and fairness in contractual clauses.

• **Implement Hybrid Models with Human Supervision**: Until full legal maturity is achieved, hybrid models that combine automated execution with human oversight offer the most practical solution. These models leverage the speed and transparency of technology while preserving flexibility for contractual justice and exceptional circumstances—especially in sensitive government and infrastructure contracts.

• **Revise Public Procurement Regulations and Executive Guidelines**: For smart contracts to enter the realm of public procurement, fundamental reforms in procurement regulations are necessary, including updates to the Government Procurement Act, financial bylaws for state-owned enterprises, and technical supervision protocols. These reforms must allow gradual implementation of smart contracts under localized, legally enforceable conditions.

• **Empower Legal, Judicial, and Engineering Experts through Cross-Disciplinary Training**: One of the biggest barriers is the lack of interdisciplinary knowledge among legal professionals. Therefore, specialized training programs on digital contracts, blockchain, and the legal implications of AI should be offered through research centers, law schools, and executive institutions. A comprehensive understanding of these technologies will enable the formation of modern legal reasoning.

• **Establish Digital Arbitration Bodies and Standardize Smart Contract Templates**: Independent arbitration institutions should be established for resolving disputes arising from smart contracts. These institutions should integrate legal, technological, and engineering expertise and operate based on principles of fairness, digital contract norms, and international arbitration standards. Moreover, developing standardized templates for smart contracts can reduce future legal uncertainties and promote safer adoption.

Ethical Considerations

All procedures performed in this study were under the ethical standards.

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Conflict of Interest

The authors report no conflict of interest.

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