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# Smart Contracts for Online Dispute Resolution: legal implications and practical applications under EU regulations

## *Gli Smart Contract per la risoluzione online delle controversie: implicazioni giuridiche e applicazioni pratiche alla luce del quadro normativo dell'Unione Europea*

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Abstract

This paper explores the integration of smart contracts into Online Dispute Resolution (ODR) systems within the EU legal framework. Analysing their potential for automation and transparency in cross-border disputes, it assesses legal gaps, regulatory challenges, and proposes policy recommendations for a harmonised and effective digital justice system in the European Union.

*Il presente contributo analizza l'integrazione degli smart contract nei sistemi di risoluzione online delle controversie (ODR) nel quadro giuridico dell'Unione Europea. Esaminando il loro potenziale in termini di automazione e trasparenza nelle controversie transfrontaliere, valuta le lacune normative, le sfide regolatorie e propone raccomandazioni di policy per un sistema di giustizia digitale armonizzato ed efficace nell'Unione Europea.*

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Keywords: Smart contracts; Online Dispute Resolution; EU law; Digital justice

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## 1. Introduction: The proliferation of digital technologies for legal purposes.

The proliferation of digital technologies continues to transform the landscape of commercial transactions and legal processes. One of the most impactful developments is the rise of Online Dispute Resolution (ODR): a method that uses digital platforms to resolve disputes more efficiently than traditional litigation. Concurrently, smart contracts, which embed contractual terms directly into self-executing code on blockchain platforms, are becoming increasingly prevalent across financial and non-financial sectors. These contracts promise to execute precisely as programmed, minimizing reliance on intermediaries. However, the integration of smart contracts within ODR systems introduces a number of unresolved legal and regulatory challenges. While ODR systems offer an innovative mechanism for pre-judicial resolution of disputes, their application to smart contracts is still relatively underdeveloped. Moreover, existing EU legal instruments lack a cohesive framework to guide their implementation, which hinders both legal certainty and market uptake. Accordingly, this paper seeks to critically examine the interplay between smart contracts and ODR in the context of European Union (EU) regulations, by asking whether and how existing legal frameworks can accommodate blockchain-based contractual enforcement within digital dispute mechanisms.[1]

Alternative Dispute Resolution (ADR) has long been promoted as a faster, more cost-effective substitute for traditional courtroom litigation. In recent decades, technological advancements have given rise to ODR, a digital evolution of ADR conducted partially or entirely online.[2] While ODR offers clear

[1] A Bokolo, 'Deployment of Distributed Ledger and Decentralized Technology for Transition to Smart Industries' (2023) 43 Environment Systems and Decisions 298; DA Zetzsche and others, 'The Markets in Crypto-Assets Regulation (MiCA) and the EU Digital Finance Strategy' (2020) ECGI Law Working Paper No 566/2020 <https://ssrn.com/abstract=3725395> accessed 2 September 2025.

[2] D Rainey, MSA Abdel Wahab and E Katsh, *Online Dispute Resolution — Theory and Practice: A Treatise on Technology and Dispute Resolution* (2nd edn, Eleven International Publishing 2021) <https://www.torrossa.com/en/resources/an/5486927> accessed 2 September 2025; EA Onţanu, 'Normalising the Use of Electronic Evidence: Bringing Technology Use into a Familiar Normative Path in Civil Procedure' (2022) 12(3) Oñati Socio-Legal Series 582 <https://doi.org/10.35295/OSLS.IISL/0000-0000-0000-1304> accessed 2 September 2025.

advantages in terms of accessibility and efficiency, it also raises critical concerns regarding party consent, data protection, and procedural fairness. Unlike traditional ADR, ODR lacks face-to-face negotiation, and decisions are often binding regardless of whether the resolution process is facilitated by AI, blockchain, or other technologies.[3]

This paper focuses specifically on the legal implications and practical applications of smart contracts within the ODR framework, with a special emphasis on their compatibility with EU regulations. It thus aims to inform both scholars and policymakers about the regulatory gaps and normative tensions that smart contract integration entails, while exploring technical affordances and their limitations.

### 1.1. Research Objectives and Questions.

The primary objective of this study is to assess the legal feasibility and practical implementation of smart contracts within the context of ODR systems regulated by the European Union. It aims to explore the compatibility of smart contracts with the ODR Regulation (EU No 524/2013) and the Directive on Consumer ADR (2013/11/EU), and to analyze their potential impact on consumer safety, procedural rights, and economic interests.[4] Thus, the research is structured around the following main question: How can smart contracts be effectively integrated into Online Dispute Resolution (ODR) systems within the European Union in a way that ensures legal enforceability, procedural fairness, and technological robustness?

To address this question, the analysis is guided by the following sub-questions:

- SRQ1: To what extent are current EU legal frameworks equipped to meet the dispute resolution needs arising from smart contracts and cryptocurrency-based transactions?
- SRQ2: How can blockchain-integrated ODR mechanisms be designed to guarantee fairness, enforceability, and compliance with procedural norms in decentralized environments?
- SRQ3: What legal, technological, and regulatory challenges arise from the convergence of smart contracts, ODR, and cryptocurrencies, and how can these be addressed through interdisciplinary approaches?
- SRQ4: What role can AI-driven tools and decentralized arbitration platforms play in enhancing the scalability and trustworthiness of dispute resolution for digital transactions?

[3] LC Voumik and others, '$CO_2$ Emissions from Renewable and Non-Renewable Electricity Generation Sources in the G7 Countries: Static and Dynamic Panel Assessment' (2023) 16(3) Energies 1044 <https://doi.org/10.3390/en16031044> accessed 2 September 2025; AJ Schmitz, 'Picking the Proper Technological Tool for Problem-Solving in Arbitration' (2023) SSRN Electronic Journal <https://doi.org/10.2139/ssrn.4608415> accessed 2 September 2025.

[4] A Ferreira, P Sandner, 'EU Search for Regulatory Answers to Crypto Assets and Their Place in the Financial Markets' Infrastructure' (2021) 43 Computer Law & Security Review 105632 <https://doi.org/10.1016/j.clsr.2021.105632> accessed 2 September 2025; S Fiorentino, S Bartolucci, 'Blockchain-Based Smart Contracts as New Governance Tools for the Sharing Economy' (2021) 117 Cities 103325 <https://doi.org/10.1016/j.cities.2021.103325> accessed 2 September 2025.

Together, these sub-questions shape the doctrinal, technological, and normative analysis developed throughout the paper and collectively contribute to answering the main research question.

This research employs a doctrinal legal methodology, supported by illustrative case studies, to analyse the legal and technological dimensions of smart contracts in ODR. The analysis is grounded in a positivist legal approach, with a focus on interpreting existing EU regulations and their application to emerging smart contract models.[5] A black-letter law framework is adopted to evaluate contract law doctrines relevant to smart contracts and to assess their enforceability within digital dispute resolution mechanisms. The geographical scope is limited to EU Member States, focusing on harmonized regulatory instruments such as Regulation No. 910/2014 (eIDAS), which defines trust services relevant to digital identification and authentication.[6] The study also examines how sectoral laws – such as competition law and virtual transaction (VT) law – interface with the enforcement of smart contract-based dispute settlements.

The methodological approach thus enables both the interpretive evaluation of binding legal norms and the functional analysis of emerging digital tools within live or near-live regulatory contexts. Two practical case studies are included to illustrate these dynamics: (1) the judicial review of the AI-based platform Verivox in the context of antitrust proceedings, and (2) the implementation of smart contract arbitration clauses in real estate and digital payment applications.[7]

## 2. Smart Contracts: Definition and Characteristics.

Online Dispute Resolution (ODR) refers to dispute resolution processes that are conducted, wholly or partially, through digital means (Rainey et al., 2021; Alessa, 2022). Its significance is particularly pronounced in cross-border transactions within the European internal market, where traditional legal processes often struggle with jurisdictional and procedural complexities.[8] EU

[5] J Chaisse, JM Kirkwood, 'Smart Courts, Smart Contracts, and the Future of Online Dispute Resolution' (2022) Stanford Journal of Blockchain Law & Policy <https://stanford-jblp.pubpub.org/> accessed 2 September 2025; H Hamledari, M Fischer, 'Role of Blockchain-Enabled Smart Contracts in Automating Construction Progress Payments' (2021) 13(1) Journal of Legal Affairs and Dispute Resolution in Engineering and Construction <https://doi.org/10.1061/(ASCE)LA.1943-4170.0000442> accessed 2 September 2025; AP Gurgun, K Koc, 'Administrative Risks Challenging the Adoption of Smart Contracts in Construction Projects' (2022) 29(2) Engineering, Construction and Architectural Management 989 <https://doi.org/10.1108/ECAM-09-2020-0678> accessed 2 September 2025.

[6] CP Sempere, 'Crypto Assets and Financial Data Space Regulation in the EU's Hybrid System of Hard and Soft Law' in Governance and Control of Data and Digital Economy in the European Single Market (2025) 71 <https://doi.org/10.1007/978-3-031-74889-9> accessed 2 September 2025; F Bassan, M Rabitti, 'From Smart Legal Contracts to Contracts on Blockchain: An Empirical Investigation' (2024) 55 Computer Law & Security Review 106035 <https://doi.org/10.1016/j.clsr.2024.106035> accessed 2 September 2025.

[7] M Cappai, 'The Role of Private and Public Regulation in the Case Study of Crypto-Assets: The Italian Move Towards Participatory Regulation' (2023) 49 Computer Law & Security Review 105831 <https://doi.org/10.1016/j.clsr.2023.105831> accessed 2 September 2025; F Zatti and others, *ELI Principles on Blockchain Technology, Smart Contracts and Consumer Protection* (European Law Institute 2022) <https://www.europeanlawinstitute.eu> accessed 2 September 2025.

[8] DA Zetzsche and others, 'The Markets in Crypto-Assets Regulation (MiCA) and the EU Digital Finance Strategy' (2020) ECGI Law Working Paper No 566/2020 <https://ssrn.com/abstract=3725395> accessed 2

consumer protection laws, grounded in *de lege ferenda* considerations, support the development of such digital platforms at the EU level. [9] Consumer protection remains a core value of the EU legal order,[10] while access to justice continues to be predominantly associated with access to courts, despite ongoing debates about the adequacy of this approach in the digital era.[11] ODR platforms have been envisioned as mechanisms to enhance product clarity, accessibility, and legal redress in the digital marketplace. In 2011, the European Commission initiated comprehensive regulatory efforts to establish a standardized ODR framework. This culminated in a web-based platform facilitating the cross-border processing and storage of disputes submitted by ODR providers.

This conceptual grounding lays the foundation for understanding the legal and technological compatibility issues addressed in SRQ1 and SRQ3, while contextualizing the EU's normative commitments to digital justice.

While the principle of party autonomy is well-established in classical contract theory, the use of blockchain-based smart contracts introduces unique challenges related to creation, enforcement, and oversight. Smart contracts, when implemented via distributed ledger technologies (DLTs), often operate without human intermediaries, prompting concerns about their enforceability and compatibility with national legal systems.[12] Legal questions persist: Are such transactions enforceable? Can they comply with public policy or mandatory legal provisions? [13] Originating from Szabo's (1994) conceptualization, smart contracts are defined as "a set of promises, specified

September 2025; J Wagner, 'The European Union's Model of Integrated Border Management: Preventing Transnational Threats, Cross-Border Crime and Irregular Migration in the Context of the EU's Security Policies and Strategies' in Patterns in Border Security (Routledge 2022) 76; M H Zakir, S Ali, 'Cross-Border Trademark Infringement in the Digital Age: Jurisdictional Challenges and Harmonization Efforts' (2023) 3(2) Pakistan Islamicus: An International Journal of Islamic and Social Sciences; K Mania, 'Online Dispute Resolution: The Future of Justice' (2015) 1(1) International Comparative Jurisprudence 76 <https://doi.org/10.1016/j.icj.2015.10.006> accessed 2 September 2025.

[9] S Rudohradská, D Treščáková, 'Proposals for the Digital Markets Act and Digital Services Act: Broader Considerations in Context of Online Platforms' (2021) 5 EU and Comparative Law Issues and Challenges Series (ECLIC) 487 <https://doi.org/10.25234/eclic/18317> accessed 2 September 2025.

[10] J Andraško, M Mesarčík, 'Those Who Shall Be Identified: The Data Protection Aspects of the Legal Framework for Electronic Identification in the European Union' (2021) 11(2) TalTech Journal of European Studies 3 <https://doi.org/10.2478/bjes-2021-0012> accessed 2 September 2025.

[11] JE Teixeira, ATC Tavares-Lehmann, 'Industry 4.0 in the European Union: Policies and National Strategies' (2022) 180 Technological Forecasting and Social Change 121664 <https://doi.org/10.1016/j.techfore.2022.121664> accessed 2 September 2025.

[12] K Ahsan, S Akbar, B Kam, 'Contract Cheating in Higher Education: A Systematic Literature Review and Future Research Agenda' (2022) 47(4) Assessment & Evaluation in Higher Education 523 <https://doi.org/10.1080/02602938.2021.1931660> accessed 2 September 2025; SN Khan and others, 'Blockchain Smart Contracts: Applications, Challenges, and Future Trends' (2021) 14(5) Peer-to-Peer Networking and Applications 2901 <https://doi.org/10.1007/s12083-021-01127-0> accessed 2 September 2025; A Dixit and others, 'Towards User-Centered and Legally Relevant Smart-Contract Development: A Systematic Literature Review' (2022) 26 Journal of Industrial Information Integration 100314 <https://doi.org/10.1016/j.jii.2021.100314> accessed 2 September 2025.

[13] S-Y Lin and others, 'A Survey of Application Research Based on Blockchain Smart Contract' (2022) 28(2) Wireless Networks 635 <https://doi.org/10.1007/s11276-021-02874-x> accessed 2 September 2025; TM Hewa and others, 'Survey on Blockchain-Based Smart Contracts: Technical Aspects and Future Research' (2021) 9 IEEE Access 87643 <https://doi.org/10.1109/ACCESS.2021.3068178> accessed 2 September 2025; G Zarra, 'Testing the Distinction Between Public Policy and Overriding Mandatory Rules' in *Imperativeness in Private International Law* (TMC Asser Press 2022) 55 <https://doi.org/10.1007/978-94-6265-499-0_2> accessed 2 September 2025.

in digital form, which are self-enforcing through software protocols".[14] These contracts encode rights, obligations, and enforcement mechanisms, thus removing the need for institutional enforcement.[15]

However, for smart contracts to be legally viable, they must include all elements necessary to constitute binding agreements. These include the digital embedding of legal norms, conditions, and enforcement triggers within the code itself. [16] These issues intersect with Research Questions 1 and 3 by underscoring the need for legislative adaptation and technological standardization.

ODR has developed in parallel with the proliferation of internet-based commerce, providing a flexible and efficient alternative to traditional dispute resolution. The earliest documented implementation occurred in 1999 in the U.S., where the Lucas County Court of Common Pleas adopted fully online procedures.[17]

The EU has been particularly proactive in this domain, promoting what has been termed "Regulatory ODR." This involves institutionalizing platforms that facilitate structured dispute resolution between consumers and traders in cross-border e-commerce.

## 3. Legal Framework for Smart Contracts in ODR.

The European Union has taken a progressive stance on regulating smart contracts and digital services, evidenced by recent proposals for the Digital Services Act and legislation on platform work.[18] Member States are expected to adopt harmonized interpretations of legal ambiguities while implementing national-level provisions consistent with overarching EU goals.[19]

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[14] P Ortolani, 'Self-Enforcing Online Dispute Resolution: Lessons from Bitcoin' (2016) 36(3) Oxford Journal of Legal Studies 595 <https://ssrn.com/abstract=2730554> accessed 2 September 2025.

[15] A Rawashdeh, 'Bridging the Trust Gap in Financial Reporting: The Impact of Blockchain Technology and Smart Contracts' (2025) 23(2) Journal of Financial Reporting and Accounting 660 <https://doi.org/10.1108/JFRA-08-2023-0494> accessed 2 September 2025; S Secinaro, D Calandra and P Biancone, 'Blockchain, Trust, and Trust Accounting: Can Blockchain Technology Substitute Trust Created by Intermediaries in Trust Accounting? A Theoretical Examination' (2021) 14(2) International Journal of Management Practice 129 <https://doi.org/10.1504/IJMP.2021.113824> accessed 2 September 2025.

[16] V Dwivedi and others, 'A Formal Specification Smart-Contract Language for Legally Binding Decentralized Autonomous Organizations' (2021) 9 IEEE Access 76069 <https://doi.org/10.1109/ACCESS.2021.3081926> accessed 2 September 2025; A Ferreira, P Sandner, 'EU Search for Regulatory Answers to Crypto Assets and Their Place in the Financial Markets' Infrastructure' (2021) 43 Computer Law & Security Review 105632 <https://doi.org/10.1016/j.clsr.2021.105632> accessed 2 September 2025.

[17] E Chioatto, P Sospiro, 'Transition from Waste Management to Circular Economy: The European Union Roadmap' (2023) 25(1) Environment, Development and Sustainability 249 <https://doi.org/10.1007/s10668-021-02050-3> accessed 2 September 2025; E Eckert, O Kovalevska, 'Sustainability in the European Union: Analyzing the Discourse of the European Green Deal' (2021) 14(2) Journal of Risk and Financial Management 80 <https://doi.org/10.3390/jrfm14020080> accessed 2 September 2025; I Ulnicane, 'Artificial Intelligence in the European Union' in *The Routledge Handbook of European Integrations* (Routledge 2022) 254 <https://doi.org/10.4324/9780429262081-19> accessed 2 September 2025.

[18] DA Zetzsche and others, 'DLT-Based Enhancement of Cross-Border Payment Efficiency – A Legal and Regulatory Perspective' (2021) 15(1–2) Law and Financial Markets Review 70 <https://doi.org/10.1080/17521440.2022.2065809> accessed 2 September 2025.

[19] JE Teixeira and ATC Tavares-Lehmann, 'Industry 4.0 in the European Union: Policies and National Strategies' (2022) 180 Technological Forecasting and Social Change 121664 <https://doi.org/10.1016/j.techfore.2022.121664> accessed 2 September 2025; L Battista, 'The European

Despite growing interest, the legal classification of smart contracts remains contested. Some jurisdictions treat them as standard electronic contracts, while others hesitate to grant them full legal standing when implemented on blockchain systems.[20]

Their legal enforceability depends heavily on party choice of law and technical standards that can verify identity and intent—elements currently lacking in uniformity across the EU (Ferreira, 2021). Smart contracts can complement rather than displace traditional legal intermediaries, requiring legislation that accounts for their societal implications.[21]

These ambiguities underscore the need for a harmonized legal ontology of smart contracts within the EU, especially regarding the parameters of digital consent, intent, and enforcement. While the EU is considering separate regulations for automated contracts, key concerns regarding party collaboration, dispute resolution, and enforcement remain inadequately addressed.[22] This section thus contributes to answering SRQ1 and SRQ2, by identifying both the progress and the critical regulatory gaps that hinder the full legal operability of smart contract-enabled ODR systems.

The rise of digital marketplaces has placed pressure on traditional legal mechanisms to offer cost-effective dispute resolution for small claims.[23] EU law currently recognizes multiple avenues for alternative dispute resolution, including statutory mediation and arbitration. Yet, a dichotomy exists between traditional ADR, grounded in legal formalism, and ODR, which increasingly relies on automated, IT-driven processes.[24]

Directives 2013/11/EU and Regulation No. 524/2013 specify required functionalities for compliant ODR systems, but lack deeper normative guidance

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Framework Agreement on Digitalisation: A Tough Coexistence Within the EU Mosaic of Actions' (2021) 1 Italian Labour Law E-Journal 14 <https://doi.org/10.6092/issn.1561-8048/13357> accessed 2 September 2025.

[20] F Heyman, PJ Norbäck and L Persson, 'Digitalisation, Productivity and Jobs: A European Perspective' in *The European Union and the Technology Shift* (Springer International Publishing 2021) 135–59 <https://doi.org/10.1007/978-3-030-63672-2_6>; I Paweloszek, N Kumar and U Solanki, 'Artificial Intelligence, Digital Technologies and the Future of Law' (2022) Futurity Economics & Law 22–32 <https://doi.org/10.57125/fel.2022.06.25.03>; J Brodny, M Tutak, 'Assessing the Level of Digitalization and Robotization in the Enterprises of the European Union Member States' (2021) 16(7) PLOS ONE e0254993 <https://doi.org/10.1371/journal.pone.0254993>.

[21] M Vatiero, 'Smart Contracts vs Incomplete Contracts: A Transaction Cost Economics Viewpoint' (2022) 46 Computer Law & Security Review 105710 <https://doi.org/10.1016/j.clsr.2022.105710>; D Wiegandt, 'Blockchain and Smart Contracts and the Role of Arbitration' (2022) 39(5) Journal of International Arbitration 671–90 <https://doi.org/10.54648/JOIA2022029>.

[22] AJ Schmitz, 'Picking the Proper Technological Tool for Problem-Solving in Arbitration' (2023) SSRN Electronic Journal <https://doi.org/10.2139/ssrn.4608415>; N Del Sarto, L Gal and F Ielasi, 'Financial Innovation: The Impact of Blockchain Technologies on Financial Intermediaries' (2024) 12(01) Journal of Financial Management, Markets and Institutions <https://doi.org/10.1142/S2282717X23500056>.

[23] ML Chiarella, 'Digital Markets Act (DMA) and Digital Services Act (DSA): New Rules for the EU Digital Environment' (2022) 9(1) Athens Journal of Law 33–58 <https://doi.org/10.30958/ajl.9-1-2>; F Lagioia and others, 'AI in Search of Unfairness in Consumer Contracts: The Terms of Service Landscape' (2022) 45(3) Journal of Consumer Policy 481–536 <https://doi.org/10.1007/s10603-022-09520-9>.

[24] B Singh, 'Unleashing Alternative Dispute Resolution (ADR) in Resolving Complex Legal-Technical Issues Arising in Cyberspace Lensing E-Commerce and Intellectual Property: Proliferation of E-Commerce Digital Economy' (2023) 5(10) Revista Brasileira de Alternative Dispute Resolution 81–105 <https://doi.org/10.52028/RBADR.V5I10.ART04.IND>; K Mania, 'Online Dispute Resolution: The Future of Justice' (2015) 1(1) International Comparative Jurisprudence 76–86 <https://doi.org/10.1016/j.icj.2015.10.006>; F Guillaume, S Riva, 'Blockchain Dispute Resolution for Decentralized Autonomous Organizations: The Rise of Decentralized Autonomous Justice' in *Blockchain and Private International Law* (Brill | Nijhoff 2023) 549-641 <https://doi.org/10.1163/9789004514850_022>.

on fairness, transparency, and accessibility.[25] These instruments provide a foundational basis for integrating smart contracts but remain silent on their code-based logic, enforceability triggers, and compatibility with general principles of consumer protection and procedural justice. For smart contract-enabled ODR platforms to be trustworthy and legally sound, regulators must address governance models, proportional costs, and data protection standards. This reflects SRQ2's focus on ensuring enforceability and procedural fairness in decentralized contexts.

Three major legal challenges persist in the enforceability of smart contracts within the EU:

- Governing Law and Jurisdiction: Determining the applicable law and competent forum remains complex due to the decentralized and borderless nature of blockchain technologies;[26]
- Dispute Resolution Mechanisms: Parties must predefine not only the dispute resolution method but also the jurisdictional authority empowered to enforce outcomes. Traditional criteria may need adaptation to address the decentralized environment;[27]
- Regulatory Compliance: Compliance with AML and counter-terrorism laws is hindered by the pseudonymous nature of blockchain transactions. Regulatory guidance is urgently needed to ensure legal traceability and consumer protection.[28]

These legal concerns directly impact the feasibility of embedding enforceable logic into ODR processes, revealing a need for enhanced legislative adaptation to emerging contractual forms (RQ1 and RQ3). The lack of uniform standards for digital consent, intent verification, and recourse mechanisms continues to inhibit broader adoption of smart contract frameworks in legally significant settings.

## 4. Technological Infrastructure and Implementation of Smart Contracts in Online Dispute Resolution (ODR).

The implementation of smart contracts within Online Dispute Resolution (ODR) platforms requires a sophisticated and well-supported technological

[25] T da Fonseca Soares, 'Arbitration and Mediation in Consumer Disputes at the Consumer's Option' (2024) 32(2) European Review of Private Law 193–220 <https://doi.org/10.54648/ERPL2024016>; F Casarosa, 'Access to Justice Through Alternative Dispute Resolution Mechanisms: Principles Emerging from the CJEU Jurisprudence' (2024) 3 Opinio Juris in Comparatione 1–23 <https://rm.coe.int/declaration-en/16809ea1e2>.

[26] P Tolmach and others, 'A Survey of Smart Contract Formal Specification and Verification' (2021) 54(7) ACM Computing Surveys (CSUR) 1–38 <https://doi.org/10.1145/3464421>.

[27] TM Hewa and others, 'Survey on Blockchain-Based Smart Contracts: Technical Aspects and Future Research' (2021) 9 IEEE Access 87643–62 <https://doi.org/10.1109/ACCESS.2021.3068178>; N Kannengiesser and others, 'Challenges and Common Solutions in Smart Contract Development' (2021) 48(11) IEEE Transactions on Software Engineering 4291–318 <https://doi.org/10.1109/TSE.2021.3116808>.

[28] I Zavoli, C King, 'The Challenges of Implementing Anti-Money Laundering Regulation: An Empirical Analysis' (2021) 84(4) The Modern Law Review 740–71 <https://doi.org/10.1111/1468-2230.12628>; FMJ Teichmann, 'Current Developments in Money Laundering and Terrorism Financing' (2023) 26(2) Journal of Money Laundering Control 337–48 <https://doi.org/10.1108/JMLC-05-2019-0043>; C Singh, W Lin, 'Can Artificial Intelligence, RegTech and CharityTech Provide Effective Solutions for Anti-Money Laundering and Counter-Terror Financing Initiatives in Charitable Fundraising' (2021) 24(3) Journal of Money Laundering Control 464–82 <https://doi.org/10.1108/JMLC-09-2020-0100>.

infrastructure. Central to this infrastructure is the selection of an appropriate blockchain platform, as each platform offers distinct capabilities, scripting languages, and integration models. For instance, Hyperledger Composer provides a robust, modular framework for permissioned networks with human-readable code, while platforms like Waves support contract development in Scala, and Ethereum enables coding directly within the business logic using Solidity.[29] These variations significantly influence how smart contracts are deployed and operated within ODR systems.

Blockchain-based smart contracts rely on digital wallets—not in the traditional sense, but as graphical user interfaces that enable users to manage identities and tokens (often Ether in Ethereum ecosystems). These interfaces are often supported by JavaScript on the client side and utilize external JSON APIs to fetch real-time data regarding account balances, transaction statuses, and market values.[30] Development tools such as browser-solidity, command-line interfaces (e.g., Geth), and Integrated Development Environments (IDEs) allow for the creation, testing, debugging, and deployment of smart contracts in an interactive and accessible manner.

These contracts are inherently dynamic and programmable. Their self-executing nature enables them to autonomously perform a series of predefined actions once specified conditions are met, significantly reducing the need for third-party enforcement. As such, smart contracts offer both transparency and immutability: two features that are foundational for enhancing trust in digital agreements. Moreover, their deployment within decentralized systems ensures resistance to tampering and provides an auditable trail of actions, facilitating enforceability in legal or quasi-legal frameworks.[31]

This section contributes to SRQ2 and SRQ4 by outlining the technical conditions necessary for smart contract enforceability and evaluating how infrastructure choices – such as platform type and language – impact regulatory compatibility and procedural reliability.

### 4.1. Blockchain Integration and Regulatory Interplay in ODR.

The convergence of blockchain technology and ODR marks a transformative phase in the legal-tech ecosystem. Originally developed to prevent double spending in cryptocurrencies, blockchain has rapidly evolved into a powerful infrastructure applicable in fields as diverse as digital identity management,

[29] P Sharma, R Jindal, MD Borah, 'A Review of Smart Contract-Based Platforms, Applications, and Challenges' (2023) 26(1) Cluster Computing 395–421 <https://doi.org/10.1007/s10586-021-03491-1>; SY Lin and others, 'A Survey of Application Research Based on Blockchain Smart Contract' (2022) 28(2) Wireless Networks 635–90 <https://doi.org/10.1007/s11276-021-02874-x>;

[30] P Tolmach and others, 'A Survey of Smart Contract Formal Specification and Verification' (2021) 54(7) ACM Computing Surveys (CSUR) 1–38 <https://doi.org/10.1145/3464421>.

[31] J Rosa-Bilbao, J Boubeta-Puig, A Rutle, 'EDALoCo: Enhancing the Accessibility of Blockchains Through a Low-Code Approach to the Development of Event-Driven Applications for Smart Contract Management' (2023) 84 Computer Standards & Interfaces 103676 <https://doi.org/10.1016/j.csi.2022.103676>; H Wu and others, 'On-Site Construction Quality Inspection Using Blockchain and Smart Contracts' (2021) 37(6) Journal of Management in Engineering <https://doi.org/10.1061/(ASCE)ME.1943-5479.0000967>.

asset registration, voting systems, and audit mechanisms.[32] Its intrinsic features – immutability, transparency, decentralization, and distributed consensus – render it a natural fit for implementing automated dispute resolution mechanisms.

In the context of ODR, blockchain serves as a foundation for embedding smart contracts into digital platforms that offer automated or semi-automated mediation and arbitration services. Some platforms integrate these tools in collaboration with regulatory frameworks, such as the EU Regulation on ODR and the EU Crowdfunding Service Providers Regulation. These developments envisage a future where accredited ODR providers can be certified to operate as authorized financial intermediaries, raising capital through tokenized ventures and verifying compliance through blockchain-backed procedures.[33]

Moreover, the regulatory landscape is gradually adapting to these innovations. The European Securities and Markets Authority (ESMA) and the European Insurance and Occupational Pensions Authority (EIOPA) are tasked with overseeing these developments, ensuring that smart contract-integrated ODR systems remain aligned with data protection obligations, such as those enshrined in the General Data Protection Regulation (GDPR), and with broader financial service regulations.[34] This regulatory interplay highlights the possibility for blockchain-integrated ODR platforms to evolve within a semi-public, semi-private architecture – responding to the need for trustable, automated legal services articulated in SRQ2 and SRQ4. However, certain contracts – such as those relating to gambling, land sales, financial services, and personal services – remain excluded from smart contract applications due to their complex legal and jurisdictional implications.[35]

## 5. Practical Implementations of Smart Contracts in ODR Systems.

The deployment of smart contracts within actual ODR settings has been particularly notable in e-commerce environments where transactions often involve standardized, low-value claims. These include disputes over delivery failures, defective goods, or refund policies. Traditional ODR mechanisms in such contexts, as seen with platforms like eBay and PayPal, rely on a combination of conciliation, mediation, and arbitration. The integration of smart contracts into such frameworks enhances efficiency by enabling

[32] A Hassan and others, 'Secured Insurance Framework Using Blockchain and Smart Contract' (2021) Scientific Programming 1–11 <https://doi.org/10.1155/2021/6787406>; D Negi and others, 'Block Chain Platforms and Smart Contracts' in *Blockchain Technology: Concepts and Applications* (Springer 2021) 65–76 <https://doi.org/10.1007/978-3-030-65691-1_5>.

[33] C Cauffman, C Goanta, 'A New Order: The Digital Services Act and Consumer Protection' (2021) 12(4) European Journal of Risk Regulation 758–74 <https://doi.org/10.1017/err.2021.8>; A Turillazzi and others, 'The Digital Services Act: An Analysis of Its Ethical, Legal, and Social Implications' (2023) 15(1) Law, Innovation and Technology 83–106 <https://doi.org/10.1080/17579961.2023.2184136>.

[34] M Bakhramovna, 'ODR (Online Dispute Resolution) System as a Modern Conflict Resolution: Necessity and Significance' (2022) 4(3) Journal of Modern Science 443–52

[35] F Amato and others, 'A Model for Verification and Validation of Law Compliance of Smart Contracts in IoT Environment' (2021) 17(11) IEEE Transactions on Industrial Informatics 7752–59 <https://doi.org/10.1109/TII.2021.3057595>; A Ferreira, P Sandner, 'EU Search for Regulatory Answers to Crypto Assets and Their Place in the Financial Markets' Infrastructure' (2021) 43 Computer Law & Security Review 105632 <https://doi.org/10.1016/j.clsr.2021.105632>.

automatic enforcement of outcomes directly tied to pre-agreed conditions in the digital agreement itself.[36] In scenarios where parties have consented in advance to the binding nature of dispute resolutions conducted via ODR systems, the final decisions can carry enforceability comparable to arbitral awards. This dual nature – automation and legal binding effect – makes smart contract-based ODR particularly suited to addressing the "Arbitrary-action-Uncertainty" (AAU) triangle identified in commercial relations, where parties either self-regulate, resort to private arbitration, or invoke public judicial authority.[37]

Despite their growing adoption, smart contracts in ODR remain primarily confined to private initiatives. Public regulatory bodies in Europe have yet to fully embrace their potential for broader legal processes, particularly in high-stakes or non-standard contract categories. [38] Nonetheless, existing frameworks such as the European Small Claims Procedure (ESCP), governed by Regulation (EU) No 861/2007, exemplify the viability of fully online dispute resolution for cross-border consumer claims under €5,000. The ESCP has opened avenues for digital enforcement of contracts arising from cross-border e-commerce, establishing a legal precedent for integrating smart contract technology into public legal systems.[39]

Notably, the success of smart contracts in such settings relies not only on technological robustness but also on the accessibility and clarity of procedures. Challenges persist, especially when national languages and forms create barriers in cross-border disputes. Yet, the growing recognition of smart contracts as viable tools in ODR underscores their potential for improving legal access and reducing friction in digital marketplaces.[40]

These empirical illustrations reinforce the relevance of smart contracts in enhancing access to justice for low-value disputes, thereby offering a real-world response to SRQ2 and SRQ4. They also underscore the importance of usability, multilingual interfaces, and legally mapped logic within ODR platforms as prerequisites for legal accessibility and consumer trust.

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[36] H Hamledari, M Fischer, 'Role of Blockchain-Enabled Smart Contracts in Automating Construction Progress Payments' (2021) 13(1) Journal of Legal Affairs and Dispute Resolution in Engineering and Construction <https://doi.org/10.1061/(ASCE)LA.1943-4170.0000442>; P Ortolani, 'A Research Agenda for Online Dispute Resolution for DLT Finance' in *A Research Agenda for Financial Law and Regulation* (2025) 237–50 <https://doi.org/10.4337/9781803929996.00019>.

[37] Y Zhao, H Chen, 'Enhancing Access to Digital Justice: Digital Governance of Dispute Resolution and Dispute Prevention in Online Commercial Activities' (2023) <https://doi.org/10.2139/ssrn.4383117>; G Pendel, I Kc Quirk, 'The Evolution and Impact of Online Dispute Resolution: Drivers, Advantages, Challenges, and Future Prospects' (2023) 10(1) BCDR International Arbitration Review 5–22 <https://doi.org/10.54648/BCDR2023012>.

[38] J Kirkwood and J Chaisse, 'Smart Courts, Smart Contracts, and the Future of Online Dispute Resolution' (2022) *Stanford Journal of Blockchain Law & Policy* (SSRN Scholarly Paper ID 4344466) <https://ssrn.com/abstract=4344466>.

[39] R Simaitis, V Vėbraitė, M Markevičiūtė, 'European Small Claims Procedure in the Realm of the Other European Proceedings' (2022) (1) Revista Ítalo-española de Derecho Procesal 123–36 https://doi.org/10.37417/rivitsproc/685; SS Salehi and M Giacalone, 'The Implementation of the European Small Claims Procedure in Belgium' (2021) (10)2 Journal of European Consumer and Market Law 80-84, <https://kluwerlawonline.com/journalarticle/Journal+of+European+Consumer+and+Market+Law/10.1/EuCML2021021>.

[40] M Giacalone, I Abignente, SS Salehi, 'Small in Value, Important in Essence: Lessons Learnt from a Decade of Implementing the European Small Claims Procedure in Italy and Belgium' (2021) 17(2) Journal of Private International Law 308–33 <https://doi.org/10.1080/17441048.2021.1953733>.

## 6. Ethical Implications of Automating Dispute Resolution.

This research has explored the intersection of smart contracts, cryptocurrencies, and online dispute resolution (ODR) systems within the context of EU legal and regulatory frameworks, critically examining the challenges and opportunities emerging from this convergence.

Dispute categories involving individuals with shared ethnic, religious, or socioeconomic profiles may require a degree of tailored procedural treatment to maintain legitimacy and normative sensitivity. However, the pre-coded nature of smart contracts may constrain such flexibility, thereby privileging certain datasets or user expectations over others. Despite the structural integrity promised by blockchain ledgers, disparities in how procedural fairness is experienced may emerge due to rigid adjudication protocols or unequal access to digital infrastructures.[41] Privacy concerns remain central to the ethical debate. Beyond the conventional analysis of individual consent or data exposure, a more holistic evaluation must consider how smart contract systems function within broader socio-technical ecosystems. Participants' trust in these technologies is shaped not only by the interface but by the alignment of systems with societal norms of fairness, accountability, and recourse.[42]

Furthermore, while ODR platforms aim to enhance accessibility, the promise of access to justice can erode quickly if systems lack the safeguards for appealing decisions, verifying accuracy, or ensuring procedural transparency. Mechanisms that allow users to challenge outcomes before impartial authorities must be a baseline requirement – an ethical and legal imperative to preserve democratic legitimacy in digital adjudication.

Smart contracts also play a dual role – not only in enforcing outcomes but in defining the procedural architecture itself. As this paper has explored, particularly in the e-commerce and consumer protection contexts, smart contracts increasingly shape the architecture of dispute resolution by embedding rules and procedural logic within the code itself. Through a normative-legal and conceptual analysis, drawing on both EU regulatory frameworks and comparative international research,[43] this study has demonstrated that while technical advancements offer clarity and automation, they also risk reproducing structural inequalities unless carefully designed and monitored.

As the European Union and other jurisdictions explore legal mechanisms to facilitate smart contract use in e-commerce dispute settings, they must balance

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[41] WS Admass, YY Munaye, AA Diro, 'Cyber Security: State of the Art, Challenges and Future Directions' (2024) 2 Cyber Security and Applications 100031 <https://doi.org/10.1016/j.csa.2023.100031>; SM Williamson, V Prybutok, 'Balancing Privacy and Progress: A Review of Privacy Challenges, Systemic Oversight, and Patient Perceptions in AI-Driven Healthcare' (2024) 14(2) Applied Sciences 675 <https://doi.org/10.3390/app14020675>.

[42] JN Chukwunweike and others, 'The Role of Deep Learning in Ensuring Privacy Integrity and Security: Applications in AI-Driven Cybersecurity Solutions' (2024) 23(2) World Journal of Advanced Research and Reviews 1778–90 <https://doi.org/10.30574/wjarr.2024.23.2.2550>.

[43] TH Pranto and others, 'A Blockchain, Smart Contract and Data Mining Based Approach Toward the Betterment of E-Commerce' (2022) 53(5) Cybernetics and Systems 443–67 <https://doi.org/10.1080/01969722.2021.2018545>; A Dixit and others, 'Towards User-Centered and Legally Relevant Smart-Contract Development: A Systematic Literature Review' (2022) 26 Journal of Industrial Information Integration 100314 <https://doi.org/10.1016/j.jii.2021.100314>.

innovation with the preservation of fundamental legal rights. The emphasis must remain on informality and flexibility, yes – but never at the expense of transparency, legal enforceability, and ethical responsibility.

This section responds directly to RQ3 and RQ4, illuminating the ethical tensions that emerge when automating adjudication logic without sufficient oversight, user recourse, or normative transparency. These ethical dilemmas must be systematically addressed through both legal design and institutional review, ensuring alignment between technological efficiency and democratic legitimacy.

## 7. Conclusions: Final considerations on the effective integration of smart contracts into ODR frameworks.

This study has examined the regulatory, technical, and normative implications of smart contracts within the evolving framework of ODR in the European Union.

Despite their early-stage implementation, smart contracts are increasingly regarded as transformative instruments for automating and enforcing online agreements, particularly in repetitive, low-value, and cross-border disputes.[44] However, they continue to operate within a legal environment that lacks comprehensive oversight, posing significant challenges for harmonization with procedural justice standards. The potential of smart contract platforms – especially within decentralized ecosystems such as e-commerce, distributed energy markets, and collaborative mobility networks – lies in their ability to standardize and automate dispute procedures with minimal reliance on traditional intermediaries. Their scalability and trustworthiness, however, remain contingent upon resolving core questions of legal enforceability, technical integrity, and procedural fairness.[45]

From a legal standpoint, current EU instruments such as the Digital Services Act, the eIDAS Regulation, and the Markets in Crypto-Assets Regulation (MiCA) offer foundational guidance yet remain insufficient in fully accommodating the automated nature and cross-jurisdictional implications of smart contract-based transactions. Particularly in civil law systems, where contractual validity is often subject to formalistic criteria, the enforceability of code-based obligations demands clearer interpretive frameworks and harmonized definitions of consent, offer, and intent. [46] Interoperability with existing enforcement

[44] D Kirli and others, 'Smart Contracts in Energy Systems: A Systematic Review of Fundamental Approaches and Implementations' (2022) 158 Renewable and Sustainable Energy Reviews 112013 <https://doi.org/10.1016/j.rser.2021.112013>; S Fiorentino, S Bartolucci, 'Blockchain-Based Smart Contracts as New Governance Tools for the Sharing Economy' (2021) 117 Cities 103325 <https://doi.org/10.1016/j.cities.2021.103325>.

[45] W van Groesen, P Pauwels, 'Tracking Prefabricated Assets and Compliance Using Quick Response (QR) Codes, Blockchain and Smart Contract Technology' (2022) 141 Automation in Construction 104420 <https://doi.org/10.1016/j.autcon.2022.104420>; H Wu and others, 'On-Site Construction Quality Inspection Using Blockchain and Smart Contracts' (2021) 37(6) Journal of Management in Engineering <https://doi.org/10.1061/(ASCE)ME.1943-5479.0000967>; P Tolmach and others, 'A Survey of Smart Contract Formal Specification and Verification' (2021) 54(7) ACM Computing Surveys (CSUR) 1.

[46] GH Kasap, 'AI Replace Human Arbitrators? Technological Concerns and Legal Implications' (2021) Journal of Dispute Resolution <https://scholarship.law.missouri.edu/jdr/vol2021/iss2/5 https://ssrn.com/abstract=3863136>.

regimes must be enhanced, particularly through improved alignment with electronic identification and trust services. Frameworks under the eIDAS Regulation should support real-time verification and adaptation of identity status, procedural permissions, and contractual relationships.[47] In this regard, a hybrid public-private partnership model may significantly enhance the credibility and adoption of smart contract infrastructures. The introduction of a "legal witness entity" paradigm could function as an institutional intermediary to verify digital identities, manage compliance layers, and foster public confidence.[48] From a fiscal and regulatory perspective, clarification is also needed as to whether blockchain-based smart contracts are to be treated as services, infrastructure, or hybrid systems. This distinction carries significant implications for taxation, liability, and compliance enforcement. Furthermore, the integration of off-chain communications and oracles for external data validation offers a promising avenue to enhance the responsiveness and contextual sensitivity of smart contracts. However, this advancement must be accompanied by robust governance mechanisms to mitigate manipulation risks and preserve the integrity of input data before the execution of smart contractual clauses.[49]

This study also sought to respond to four foundational research questions and proposes the following synthesized findings and reflections:

- On the adequacy of EU legal frameworks (SRQ1): While partial provisions exist, current EU legal instruments are not yet fully equipped to address the dispute resolution needs emerging from smart contracts and cryptocurrency-based interactions. A harmonized, code-aware legal infrastructure is needed to ensure enforceability, legitimacy, and scalability.
- On designing f air and enforceable blockchain-based ODR mechanisms (SRQ2): Ensuring procedural fairness and legal compliance in decentralized systems requires that blockchain-integrated ODR platforms are embedded with legal safeguards – such as transparent rules of engagement, appeal mechanisms, and authenticated identities. The use of eIDAS-compliant identification systems, oracles, and legally mapped smart clauses can bridge the gap between code and law.
- On the legal, regulatory, and technological challenges (SRQ3): The convergence of ODR, smart contracts, and cryptocurrency raises interdisciplinary challenges involving legal uncertainty, technical immutability, and regulatory fragmentation. Addressing these requires

[47] C Timón López, 'The eIDAS2 Regulation: The European Union's Strategic Vision to Regulate a Digital Identity Metasystem under Citizens' Control as a Public Service / El Reglamento eIDAS2: la Visión Estratégica de la Unión Europea para Regular un Metasistema de Identidad Digital bajo el Control del Ciudadano como Servicio Público' (2024) <http://hdl.handle.net/10201/142101>; EA Onţanu, 'Normalising the Use of Electronic Evidence: Bringing Technology Use into a Familiar Normative Path in Civil Procedure' (2022) 12(3) Oñati Socio-Legal Series 582 <https://doi.org/10.35295/OSLS.IISL/0000-0000-0000-1304>.

[48] J Laux, S Wachter, B Mittelstadt, 'Trustworthy Artificial Intelligence and the European Union AI Act: On the Conflation of Trustworthiness and Acceptability of Risk' (2024) 18(1) Regulation & Governance 3 <https://doi.org/10.1111/rego.12512>; A Chiappetta, 'Navigating the AI Frontier: European Parliamentary Insights on Bias and Regulation, Preceding the AI Act' (2023) 12(4) Internet Policy Review <https://doi.org/10.14763/2023.4.1733>.

[49] TK Agrawal and others, Demonstration of a blockchain-based framework using smart contracts for supply chain collaboration (2023) 61(5) International Journal of Production Research 1497–1516. <https://doi.org/10.1080/00207543.2022.2039413>.

coordinated regulatory innovation, drawing from both legal practice and software engineering.

- On the role of AI and decentralized arbitration (SRQ4): AI-driven tools and decentralized arbitration platforms offer considerable promise in enhancing the scalability, accessibility, and reliability of digital justice systems. Yet, their success depends on ensuring algorithmic transparency, ethical safeguards, and compatibility with procedural justice principles – particularly in high-volume, low-value transaction contexts such as cross-border e-commerce.[50] Scalability must never come at the expense of democratic oversight and individual rights.

Looking ahead, this research highlights the urgent need for empirical validation of smart contracts in live ODR environments. The proposed experimental model aims to test the efficacy, trustworthiness, and justice-sensitivity of these systems in real-world settings. Such validation is critical not only to refine technological design but also to ensure alignment with fundamental rights, procedural guarantees, and principles of accountability. Future interdisciplinary research should explore:

- the refinement of legal standards for digital enforceability in automated contracts;
- the development of interoperable public-private identity ecosystems;
- the integration of human oversight into algorithmic dispute resolution processes;
- the impact of legal design and user experience on access to digital justice; and
- the implementation of AI-powered technologies for ODR's triage, prediction, and result assessment processes.

In conclusion, the findings of this study suggest that the effective integration of smart contracts into ODR frameworks must go beyond technological sophistication. It must be grounded in legal certainty, ethical foresight, and procedural legitimacy. Only through such a multidimensional approach can the EU - and other jurisdictions - ensure that technology serves not merely efficiency, but justice itself.

[50] AJ Schmitz, 'Picking the Proper Technological Tool for Problem-Solving in Arbitration' (2023) SSRN Electronic Journal <https://doi.org/10.2139/ssrn.4608415>; BE Howell, PH Potgieter, 'Uncertainty and Dispute Resolution for Blockchain and Smart Contract Institutions' (2021) 17(4) Journal of Institutional Economics 545 <https://doi.org/10.1017/S1744137421000138>; O Elias Oluwafemi and others, 'The Evolution of Green Fintech: Leveraging AI and IoT for Sustainable Financial Services and Smart Contract Implementation' (2024) 23(1) World Journal of Advanced Research and Reviews 2710 <https://doi.org/10.30574/wjarr.2024.23.1.2272>.