

INTEROPERABILITY CHALLENGES IN CROSS-BORDER ELECTRONIC JUSTICE SYSTEMS: A COMPARATIVE ANALYSIS OF METHODOLOGICAL APPROACHES

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Abstract. This article examines the critical interoperability challenges facing cross-border electronic justice systems, particularly within the European Union framework. As judicial cooperation intensifies in the digital age, various methodological approaches have emerged to address the technical, semantic, organizational, and legal barriers to effective transnational information exchange in criminal and civil proceedings. Through a comprehensive analysis of existing frameworks, including e-CODEX, the European Investigation Order (EIO), and emerging e-Evidence initiatives, this research identifies persistent obstacles to seamless judicial data exchange across jurisdictions. The comparative methodology reveals that interoperability challenges stem from four primary dimensions: technical infrastructure disparities, semantic inconsistencies in data standards, organizational fragmentation, and legal framework incompatibilities. The findings demonstrate that integrated methodological approaches combining technical standardization with legal harmonization offer the most promising path forward, while respecting the complexities of national sovereignty in judicial matters. This research contributes to the scholarly understanding of cross-border electronic justice by proposing a holistic interoperability framework that balances efficiency with fundamental rights protections in the evolving landscape of transnational justice cooperation.

Keywords: electronic justice, interoperability, cross-border judicial cooperation, e-CODEX, European Investigation Order, legal frameworks, digital justice

Introduction

The digital transformation of justice systems has become a strategic imperative for many jurisdictions worldwide, driven by the need for enhanced efficiency, accessibility, and resilience of judicial processes. This transformation has been accelerated by the COVID-19 pandemic, which exposed the vulnerabilities of traditional paper-based processes and highlighted the urgent need for digital alternatives. In the European context, the development of cross-border electronic justice systems has gained particular significance due to the free movement of citizens and the resulting implications for judicial cooperation across Member States.

Interoperability – the ability of different systems to work together seamlessly – represents the cornerstone of effective cross-border electronic justice. However, achieving interoperability in this domain presents multifaceted challenges stemming from the inherent complexities of interfacing diverse national legal systems, technical infrastructures, and organizational processes. As the World Bank's ID4D initiative notes, interoperability frameworks require defining several key layers: legal interoperability (encompassing regulatory frameworks), organizational interoperability (defining trust frameworks and process standards), semantic interoperability (ensuring consistent meaning of exchanged data), and technical interoperability (enabling machine-to-machine communication) (World Bank, 2025). These layers are particularly complex in the justice domain, where sovereignty concerns and fundamental rights protections add additional dimensions to the interoperability challenge.

The European Union has made significant strides in addressing these challenges through initiatives such as e-CODEX (e-Justice Communication via Online Data Exchange) and the European Investigation Order (EIO), which aim to streamline cross-border judicial cooperation. As described by eu-LISA, e-CODEX serves as "a decentralised IT system that provides an interoperable solution for cross-border exchange of judiciary data, thus allowing all Member States to communicate with each other using their existing national systems" (eu-LISA, 2024). Despite these advances, significant obstacles remain, ranging from technical incompatibilities to legal barriers and organizational resistance.

This research article aims to systematically analyze the interoperability challenges in cross-border electronic justice systems through a comparative lens, examining various methodological approaches developed to address these challenges. The central research questions guiding this investigation are: What are the primary interoperability barriers impeding effective cross-border electronic justice cooperation? How do existing methodological frameworks address these barriers? And what promising approaches emerge from comparative analysis that could enhance future interoperability initiatives?

The significance of this research lies in its potential to inform more effective policy and technical solutions for cross-border electronic justice systems. As the European Commission (2021) has emphasized in its initiative on digitalizing cross-border judicial cooperation, "most data exchanges in cross-border judicial cooperation still take place on paper," which is "slower and less efficient than using electronic means" and "particularly vulnerable to crises". By identifying common patterns across different methodological approaches, this research contributes to the scholarly understanding of interoperability challenges and provides insights for practitioners and policymakers working to enhance cross-border judicial cooperation.

The article proceeds as follows: The first section reviews the relevant literature on interoperability in cross-border electronic justice systems, establishing the conceptual framework for the analysis. The second section outlines the methodology employed for the comparative analysis. The third section presents the findings of the analysis, identifying common patterns and divergences across different methodological approaches. The fourth section discusses the implications of these findings for policy and practice, offering recommendations for enhancing interoperability in cross-border electronic justice systems. The final section concludes with reflections on future research directions.

Literature Review

The challenge of achieving interoperability in cross-border electronic justice systems has attracted growing scholarly attention as digital transformation initiatives in the justice sector have gained momentum. This literature review synthesizes existing research on interoperability challenges and methodological

approaches in this domain, establishing the conceptual framework for the comparative analysis.

Conceptualizing Interoperability in Electronic Justice

Interoperability in the context of electronic justice encompasses multiple dimensions that extend beyond purely technical considerations. As research on European interoperability frameworks has shown, factors impeding interoperability include "organizational and administrative fragmentation (including administrative silos, slow pace of reform, legacy processes), legal obstacles (especially in cross-border settings), and lack of cooperation on and shared governance" (Kouroubali & Katehakis, 2019). This multidimensional nature of interoperability poses significant challenges for cross-border justice systems, where differences in legal traditions, administrative structures, and technological capabilities often create barriers to seamless cooperation.

The concept of interoperability in electronic justice has evolved from a primarily technical focus to a more comprehensive understanding that encompasses legal, organizational, and semantic dimensions. For instance, a model of legal interoperability for cross-border services has been proposed "based on major domains: protection and security of data, transparency and liability, further analyzed in multiple axes and combined with EU targets, policy priorities and basic European legal principles" (Nigri & Di Maio, 2020). This evolution reflects growing recognition that effective interoperability requires alignment across multiple layers, from technical protocols to legal frameworks.

Cross-Border Judicial Cooperation Frameworks

The development of cross-border judicial cooperation frameworks has significantly shaped approaches to interoperability in electronic justice. Traditional instruments such as "mutual legal assistance treaties, and the European Investigation Order allow for the lawful collection of electronic information in cross-border proceedings" through "formal judicial cooperation between competent authorities in the different countries concerned" (Stefan & González Fuster, 2018). These frameworks provide the legal foundation for cross-border information exchange but often face implementation challenges when translated into electronic processes.

The evolution of cooperation frameworks reveals a tension between traditional judicial cooperation mechanisms and emerging direct cooperation models. Recent initiatives promote "a model of direct private-public cross-border cooperation under which service providers receive, assess and respond directly to a foreign law enforcement order to produce or preserve electronic information" (Stefan & González Fuster, 2018). This shift raises important questions about the role of judicial authorities in safeguarding fundamental rights and ensuring the integrity of cross-border evidence exchange.

Technical Approaches to Interoperability

Technical approaches to addressing interoperability challenges in electronic justice have focused on developing common standards, protocols, and platforms to enable seamless information exchange. Projects like e-CODEX have been developed to facilitate "electronic exchange of orders and evidence, based on the European Investigation Order and the related client 'eEvidence Reference Implementation'" (Bille et al., 2020). These technical solutions aim to create interoperability layers that can bridge differences between national systems without requiring complete harmonization of underlying infrastructures.

The development of semantic standards has emerged as a crucial component of technical interoperability approaches. Efforts to address "interoperability issues, data security and privacy concerns, and infrastructure disparities" have included work on "universal interoperability standards, employing advanced technologies like blockchain, and harmonising health data regulations" (Bincoletto, 2020). While these approaches have been most extensively developed in the health sector, similar principles are increasingly applied to electronic justice systems.

Legal and Organizational Challenges

Legal and organizational challenges present significant barriers to interoperability in cross-border electronic justice systems. Research has identified issues including "organizational and administrative fragmentation" and "legal obstacles (especially in a cross-border setting)" as major impediments to interoperability initiatives (Kalvet et al., 2018). These challenges are particularly acute in the justice domain, where national sovereignty concerns and constitutional principles regarding judicial independence often constrain harmonization efforts.

The intersection of data protection regulations and cross-border data sharing requirements creates particularly complex challenges for electronic justice interoperability. Studies have noted that "interoperability of EHRs is inevitably bound with data protection issues because of the processing of personal data" and requires policies "to ensure compliance with guiding principles such as the GDPR" (Bincoletto, 2020). Similar tensions arise in the justice context, where the need for efficient information exchange must be balanced with robust data protection safeguards.

Research Gaps and Contribution

Despite growing literature on electronic justice systems, significant gaps remain in our understanding of interoperability challenges in cross-border contexts. Researchers have noted a "knowledge gap... as to the exact ways in which [legal] instrument[s] and MLA agreements are implemented in judicial and administrative practices across EU Member State[s], as well as in bilateral cooperation frameworks with key international partners" (Stefan & González Fuster, 2018). This research aims to address this gap by providing a comparative analysis of methodological approaches to interoperability challenges.

Furthermore, existing research has often focused on either technical or legal aspects of interoperability, with less attention to integrated approaches that address interoperability holistically. As noted in research on e-Justice in Europe, "contributing to design research" requires "novel methodological references" and "an actionable governance framework" that considers "digital, legal, and social factors" together (Velicogna, 2011). This research contributes to filling this gap by analyzing methodological approaches that span technical, legal, organizational, and semantic dimensions of interoperability.

Methodology

This research employs a comparative methodology to analyze different approaches to addressing interoperability challenges in cross-border electronic justice systems. The comparative approach allows for the identification of common patterns, divergences, and best practices across different methodological frameworks, providing insights that can inform more effective approaches to interoperability.

Research Design

The research design follows a qualitative comparative analysis approach, examining multiple case studies of methodological frameworks developed to address interoperability challenges in cross-border electronic justice systems. This approach draws on established methods for systematic review in legal and technological domains, employing "thematic content analysis" to enable "the descriptive presentation of qualitative data" and help "identify, analyse, and interpret patterns of meaning" within the analyzed frameworks (Creswell, 2009).

The comparative analysis is structured around four key dimensions of interoperability identified in the literature review: technical, semantic, organizational, and legal. For each dimension, the analysis identifies the key challenges addressed by different methodological frameworks, the approaches employed to address these challenges, and the strengths and limitations of these approaches. This structured comparison allows for the identification of common patterns and divergences across different frameworks.

Data Collection

Data for this analysis was collected through a systematic review of academic literature, policy documents, technical specifications, and evaluation reports related to cross-border electronic justice systems. The data collection followed a rigorous protocol based on "five features for a systematic literature review" as outlined by methodological experts Denyer and Tranfield (2009). This included defining clear inclusion and exclusion criteria, using multiple search strategies to identify relevant sources, and systematically extracting data using a standardized template.

The primary sources for this analysis included official documentation of major European initiatives such as e-CODEX, the European Investigation Order, and e-Evidence, as well as academic evaluations of these initiatives. The data collection also encompassed "published works about the global interoperability of information systems, international standards on digital forensics, the cross-border nature of crimes requiring procedural rules for digital evidence handling, and digital evidence collection across multiple jurisdictions" (Pardo & Tayi, 2007). This comprehensive approach ensured that the analysis captured diverse perspectives on interoperability challenges and approaches.

Analytical Framework

The analytical framework for this research is based on a multi-layered model of interoperability that encompasses technical, semantic, organizational, and legal dimensions. This framework aligns with established interoperability models, which define "four interoperability layers: Legal interoperability—Legal, policy, and regulatory frameworks; Organizational interoperability—trust frameworks and process standards; Semantic interoperability—data standards; and Technical interoperability—technology standards" (World Bank, 2025).

Within each dimension, the analysis employs a set of evaluative criteria derived from the literature review:

1. Technical dimension: standards adoption, infrastructure compatibility, security implementation, and scalability
2. Semantic dimension: data model harmonization, vocabulary standardization, metadata consistency, and interpretability
3. Organizational dimension: process alignment, governance structures, stakeholder engagement, and capability development
4. Legal dimension: regulatory alignment, fundamental rights protection, jurisdictional clarity, and enforcement mechanisms

These criteria provide a structured framework for comparing different methodological approaches and identifying their respective strengths and limitations in addressing interoperability challenges.

Case Selection

The cases selected for analysis represent major methodological frameworks developed to address interoperability in cross-border electronic justice systems, with a focus on European initiatives due to their advanced development and comprehensive documentation. The primary cases include e-CODEX, the European Investigation Order (EIO), and emerging e-Evidence initiatives, which represent different approaches to facilitating "cross-border exchange of judiciary data" and "the lawful collection of electronic information in cross-border proceedings" (Stefan & González Fuster, 2018; eu-LISA, 2024).

The e-CODEX case represents a technical infrastructure approach that "provides for a collaboration based on software elements and includes the development of uniform semantics and common standards for an exchange of documents and data as well as for identity management" (European Commission,

2020). The EIO case represents a legal framework approach that establishes procedural standards for cross-border evidence collection. The e-Evidence initiatives represent emerging integrated approaches that combine technical and legal elements to address specific challenges related to electronic evidence.

Limitations

The methodology employed in this research has several limitations that should be acknowledged. First, the focus on European initiatives, while justified by their advanced development, limits the generalizability of findings to other regional contexts. Second, the reliance on published documentation may not capture all operational challenges experienced in practice, particularly for recent initiatives with limited evaluation data. Third, the rapid evolution of both technology and legal frameworks in this domain means that some findings may become outdated as new approaches emerge.

Despite these limitations, the comparative methodology provides valuable insights into patterns and principles that transcend specific implementations and can inform future approaches to interoperability in cross-border electronic justice systems.

Results

The comparative analysis of methodological approaches to interoperability challenges in cross-border electronic justice systems reveals both common patterns and notable divergences across the examined frameworks. This section presents the findings organized by the four dimensions of interoperability: technical, semantic, organizational, and legal.

Technical Interoperability Challenges and Approaches

The analysis reveals that technical interoperability presents significant challenges in cross-border electronic justice systems, particularly related to disparate national infrastructures, security requirements, and communication protocols. Key challenges identified include "interoperability issues, data security and privacy concerns, and infrastructure disparities" that impede seamless information exchange across borders (Bincoletto, 2020).

Different methodological approaches have emerged to address these technical challenges. The e-CODEX approach employs a decentralized architecture that "consists of a connector and a gateway" where "the installation of the gateway

ensures a secured connection with a gateway in another Member State" while "the connector carries out the adaptations required for receiving encrypted data" (eu-LISA, 2024). This approach allows national systems to maintain their existing infrastructure while adding an interoperability layer for cross-border communication.

Other approaches focus on developing common standards and protocols, such as the "CASE/UCO Ontologies" for evidence exchange, which provide standardized formats for representing and transferring electronic evidence (Bille et al., 2020). These standardization efforts aim to establish common technical languages that can be implemented across different national systems without requiring complete infrastructure overhaul.

A significant technical challenge identified across frameworks is the handling of large data transfers, particularly for electronic evidence. As noted in technical documentation, addressing "the Exchange of Large File of Evidence" is "crucial... to streamline the cross-border cooperation in judicial matters" (Bille et al., 2020). Different approaches to this challenge include file segmentation, distributed storage, and specialized transfer protocols optimized for judicial data.

Semantic Interoperability Challenges and Approaches

Semantic interoperability emerges as a critical dimension of cross-border electronic justice systems, encompassing challenges related to data definitions, document structures, and the interpretation of legal concepts across different jurisdictions. The analysis underscores the importance of "semantic interoperability" to "ensure that the meaning of exchanged data and information is consistent" by adopting "the same data standards or construct data dictionaries" (World Bank, 2025).

Methodological approaches to semantic interoperability vary across frameworks. The e-CODEX approach emphasizes the development of "message structures... based on a shared EU e-Justice Core Vocabulary, ensuring a consistent and sustainable structure and definition of semantic terms used across different [Digital Procedural Standards]" (eu-LISA, 2024). This shared vocabulary approach aims to establish common understandings of key concepts while allowing for national variations in implementation.

Other frameworks focus on developing structured data models tailored to specific procedural contexts. For example, the European Investigation Order uses "a standard form" that must be "translated into the official language of the executing EU country" to ensure consistent interpretation across jurisdictions (European Commission, 2014). This form-based approach provides structured templates for data exchange while accommodating linguistic diversity.

A common challenge identified across frameworks is balancing standardization with the need to respect national legal traditions and terminology. As noted in analyses of digital justice initiatives, "national law of the Member States continues to govern questions relating to the authenticity, accuracy and appropriate legal form of documents or information" even as they "transit through the new digital channels" (European Commission, 2023). This creates tension between the need for semantic consistency and the principle of national procedural autonomy.

Organizational Interoperability Challenges and Approaches

Organizational interoperability encompasses challenges related to process alignment, governance structures, and institutional cooperation across borders. The analysis identifies significant barriers including "organizational and administrative fragmentation (including administrative silos, slow pace of reform, legacy processes)" and "lack of cooperation on and shared governance of interoperability initiatives" (Kouroubali & Katehakis, 2019).

Different methodological approaches have been developed to address these organizational challenges. The e-CODEX governance model emphasizes the creation of "Digital Procedural Standards (DPS)" that "describe the conduct of the cross-border procedure, complying with the respective legal instruments at EU level and taking into account the specifics of national implementation" (eu-LISA, 2024). This approach aims to establish common process frameworks while respecting national implementation differences.

Other approaches focus on building institutional networks and cooperation mechanisms. For example, Eurojust plays a key role in facilitating the use of the European Investigation Order by "organizing expert meetings and workshops and publishing reports informing on best practice and key findings from EIO-related

events" (Eurojust, 2020). These knowledge-sharing activities aim to build common understanding and practices across national judicial authorities.

A persistent challenge identified across frameworks is balancing centralized governance with the principle of subsidiarity. As noted in evaluations of e-CODEX, the approach "helps to implement the spirit of subsidiarity even in the field of European electronic communication in legal matters" by enabling "a Europe-wide data exchange... without putting in question any of the IT applications that are already in use on national level" (European Commission, 2020). This tension between harmonization and national autonomy remains a central organizational challenge.

Legal Interoperability Challenges and Approaches

Legal interoperability presents some of the most complex challenges for cross-border electronic justice systems, involving questions of jurisdiction, fundamental rights protection, data protection, and procedural guarantees. The analysis highlights concerns about "judicial independence" and the risks that cross-border data exchange might "constitute a danger not only for the fundamental rights of the persons concerned, but also for the independence of the judiciary and the EU rule of law as a whole" (Stefan & González Fuster, 2018).

Different methodological approaches have emerged to address these legal challenges. The European Investigation Order approach is "based on mutual recognition, which means that the executing authority is, in principle, obliged to recognise and ensure execution of the request of the other country" while establishing specific grounds for refusal to safeguard fundamental rights (Eurojust, 2020). This approach balances efficient cooperation with safeguards against potential rights violations.

Other frameworks focus on establishing legal interoperability through direct applicability of EU regulations. For instance, the Digital Justice Regulation "constitutes an important step in the EU commitment to modernise cross-border proceedings in the European judicial area" by establishing "a uniform legal framework for the use of electronic communications" while ensuring "all the necessary safeguards must be put in place" (European Commission, 2023). This directly applicable regulatory approach aims to create legal certainty across member states.

A significant legal challenge identified across frameworks is reconciling data protection requirements with efficient information exchange. As noted in analyses of cross-border data flows, effective approaches require "developing interoperability between digital economies at varying levels of development" and establishing "a high-standard framework for data protection and digital trade" (ITIF, 2021). This balance remains particularly challenging in the judicial context, where sensitive personal data often forms essential evidence.

Integration of Approaches Across Dimensions

The analysis reveals that the most promising methodological approaches to interoperability challenges integrate solutions across multiple dimensions rather than addressing each dimension in isolation. Research on e-Justice in Europe underscores that "only by taking into account digital, legal, and social factors can we design better systems that promote access to justice, the rule of law, and, ultimately social peace" (Velicogna, 2011).

Integrated approaches typically combine technical infrastructure development with legal framework harmonization, process standardization, and semantic alignment. For example, training frameworks for cross-border electronic justice systems like TREIO provide "for the legal and business sides of the European Investigation Order" as well as "sessions on the functional use of available tools and technical issues, including demos and tutorials on the use of e-Evidence Digital Exchange System and e-CODEX" (TREIO, 2022). This integrated approach recognizes the interdependence of different interoperability dimensions.

A key pattern observed across successful approaches is the iterative development of interoperability solutions through piloting and progressive implementation. As noted in analyses of cross-border services, effective approaches often follow a strategy of developing "technical solutions" and evaluating them "by means of several mobile pilot applications" before broader implementation (Fraunhofer, 2022). This iterative approach allows for learning and adaptation across all dimensions of interoperability.

Discussion

The findings of this comparative analysis have significant implications for understanding interoperability challenges in cross-border electronic justice systems and developing effective methodological approaches to address these challenges.

This section discusses the key insights emerging from the analysis and their implications for theory and practice.

Balancing Standardization and Flexibility

A central tension identified across methodological approaches is the need to balance standardization for interoperability with flexibility to accommodate national differences. As observed in analyses of interoperability frameworks, the concept of "digital interoperability" recognizes "that countries have differing legal, political, and social values and systems" while seeking to ensure that they "each provides a similar level of protection or similarly addresses a shared objective, even if their specific legal and regulatory frameworks differ" (ITIF, 2021).

This tension is particularly acute in the justice domain, where national legal traditions and constitutional principles often constrain harmonization efforts. Successful approaches like e-CODEX demonstrate that interoperability can be achieved without full harmonization by creating "a Europe-wide data exchange... without putting in question any of the IT applications that are already in use on national level" (European Commission, 2020). This suggests that methodological approaches should focus on creating interoperability layers rather than imposing uniform systems.

The implications for future interoperability initiatives include the need to develop adaptive standards that establish minimum requirements for interoperability while allowing for national variations in implementation. This aligns with approaches that define multiple "interoperability layers" addressing different aspects of cross-border cooperation while respecting national sovereignty in core domains (World Bank, 2025).

Multi-Level Governance for Interoperability

The analysis highlights the importance of appropriate governance structures for managing interoperability across different jurisdictional levels. Research on interoperability frameworks in the EU context notes the "additional element of complexity in the e-Government interoperability landscape" created by "the different administrative levels involved (local, regional, national, and the EU level)" (Kouroubali & Katehakis, 2019). This complexity requires sophisticated governance approaches that can coordinate actions across multiple levels while respecting the principle of subsidiarity.

Effective governance models identified in the analysis typically involve a combination of centralized standard-setting with decentralized implementation. For example, e-CODEX governance involves defining common "Digital Procedural Standards" at the EU level while allowing for national implementation that takes "into account the specifics of national implementation of these public services" (eu-LISA, 2024). This balanced approach ensures consistency in core interoperability elements while respecting national autonomy in implementation.

The implications for practice include the need to develop multi-level governance structures that clearly define responsibilities at each level and establish effective coordination mechanisms. Recent EU initiatives exemplify this approach by focusing on "ensuring that the different Member States' IT systems are interoperable and can communicate with each other" while recognizing the continued role of national authorities in implementation (European Commission, 2021).

Rights-Based Approach to Interoperability

A significant insight from the analysis is the importance of embedding fundamental rights protections within interoperability frameworks rather than treating them as external constraints. Traditional approaches to cross-border judicial cooperation rely on "subjecting foreign actors' requests for data to domestic independent judicial scrutiny" to "guarantee that the information sought during an investigation is lawfully obtained and admissible in court" (Stefan & González Fuster, 2018). As electronic justice systems evolve, these protections must be integrated into technical and organizational interoperability frameworks.

Emerging approaches increasingly incorporate rights protections as design requirements rather than afterthoughts. For instance, new digital justice frameworks emphasize that "all the necessary safeguards must be put in place to prevent social exclusion of certain litigants, while ensuring mutual trust between authorities, interoperability and the security of processes and data" (European Commission, 2023). This integrated approach recognizes that effective interoperability requires both efficiency and legitimacy.

The implications for future interoperability initiatives include the need to incorporate fundamental rights impact assessments into the design phase and to develop technical safeguards that operationalize legal protections. Models of legal

interoperability that combine "protection and security of data, transparency and liability" with "EU targets, policy priorities and basic European legal principles" offer promising templates for this rights-based approach (Nigri & Di Maio, 2020).

Technical Standardization and Legal Innovation

The analysis reveals important interactions between technical standardization efforts and legal framework development in addressing interoperability challenges. These interactions are particularly evident in the domain of electronic evidence, where traditional legal instruments like the European Investigation Order are being complemented by specialized frameworks like the proposed European Production Order that address the unique characteristics of electronic data (Tosza, 2020).

Successful approaches increasingly recognize the need for co-evolution of technical standards and legal frameworks. For example, training frameworks for cross-border electronic justice systems now integrate "legal and business sides" with "functional use of available tools and technical issues" to ensure that practitioners understand both the legal requirements and technical capabilities of interoperability solutions (TREIO, 2022).

The implications for theory and practice include the need for closer collaboration between technical and legal experts in developing interoperability solutions. Methods such as "soft systems methodology" offer promising approaches for addressing "the global interoperability of information systems, international standards on digital forensics, the cross-border nature of crimes requiring procedural rules for digital evidence handling, and digital evidence collection across multiple jurisdictions" (Checkland, 2011) in an integrated manner.

Capacity Building for Interoperability

A critical factor identified across successful interoperability approaches is investment in capacity building for all stakeholders involved in cross-border electronic justice systems. As noted in evaluations of training frameworks, effective implementation requires not only technical infrastructure but also "providing for the legal and business sides" and ensuring that practitioners can effectively use "available tools" (TREIO, 2022).

Capacity building approaches vary across frameworks but typically include a combination of formal training, knowledge sharing networks, and practical

experience through pilot implementations. For example, projects like FILIT aim to "provide judicial training for bailiffs and lawyers... on EU civil and commercial matters, family law, data protection, and fundamental rights" through "cross-border training activities, interprofessional training and blended learning methodology" (European Union of Bailiffs Foundation, 2020). These comprehensive approaches recognize the multidimensional nature of the knowledge required for effective interoperability.

The implications for practice include the need to develop integrated capacity building strategies that address technical, legal, organizational, and semantic aspects of interoperability. Innovative approaches such as "real-time training possibilities for more realistic and immersive sessions" that allow users to "see proof of delivery, trust-OK tokens, and other relevant information in real-time" (TREIO, 2022) offer promising models for building practical interoperability skills.

Conclusion

This research has explored the interoperability challenges facing cross-border electronic justice systems and the various methodological approaches developed to address these challenges. Through a comparative analysis focused on technical, semantic, organizational, and legal dimensions of interoperability, the research has identified common patterns, persistent challenges, and promising approaches that can inform future initiatives in this domain.

The findings reveal that interoperability in cross-border electronic justice systems is a multidimensional challenge that requires integrated approaches spanning technical infrastructure, semantic standards, organizational processes, and legal frameworks. Successful approaches recognize that "only by taking into account digital, legal, and social factors can we design better systems that promote access to justice, the rule of law, and, ultimately social peace" (Velicogna, 2011).

Key insights from the analysis include the importance of balancing standardization with flexibility to accommodate national differences, the need for multi-level governance structures that coordinate actions across jurisdictional levels, the value of embedding fundamental rights protections within interoperability frameworks, the benefits of co-evolving technical standards and

legal frameworks, and the necessity of comprehensive capacity building for all stakeholders involved in cross-border electronic justice systems.

These insights have significant implications for both theory and practice in the field of electronic justice. For scholars, they highlight the need for interdisciplinary approaches that can address the complex interactions between technical, legal, organizational, and semantic dimensions of interoperability. For practitioners and policymakers, they offer guidance for developing more effective interoperability solutions that balance efficiency with legitimacy while respecting national sovereignty in judicial matters.

As cross-border electronic justice systems continue to evolve, further research will be needed to evaluate the effectiveness of emerging approaches and to develop new methodologies for addressing persistent interoperability challenges. Particularly important areas for future investigation include the impact of organizational and administrative fragmentation on interoperability initiatives, the role of different governance models in facilitating cross-border cooperation, and the effectiveness of various approaches to balancing standardization with national autonomy (Kouroubali & Katehakis, 2019).

The digital transformation of justice systems presents both opportunities and challenges for cross-border cooperation. By developing integrated methodological approaches to interoperability that address technical, semantic, organizational, and legal dimensions in a balanced manner, we can harness the potential of digital technologies to enhance access to justice across borders while safeguarding fundamental rights and respecting national legal traditions.

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