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# Use of digital technologies to optimize investigative actions at the pre-trial stage of criminal proceedings

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**Abstract:** The relevance of the study was determined by the need for regulatory and legal incorporation of digital technologies at the pre-trial stage of criminal proceedingsThe aim of the study is to substantiate the indicator-based and model-

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based verification of digital technologies relevant to procedural integration at the pre-trial stage of criminal proceedings, taking into account regulatory traceability, evidentiary relevance, and legal incorporation. Research methods: legal analysis of norms and regulations, topological classification of digital technologies, formalization of the optimal case, indicator-based and model-based verification, legal modelling. The study carried out indicator-based and legal stratification of digital technologies at the pre-trial stage of criminal proceedings. It was established that Digital Forensics, AI, Biometrics, e-Evidence Exchange and Video Conferencing demonstrate the highest institutionalization, regulatory incorporation and evidentiary validity. Indicator-based modelling (ΔTPI, DEQ, PII, EII, UAE, DJC) confirmed their legal compliance and procedural efficiency. The highest level of regulatory integration (4 out of 5 categories) was established for Digital Forensics, Biometrics, e-Evidence Exchange, and Video Conferencing technologies. Instead, Blockchain and Digital Twin/3D were identified as auxiliary, as they require additional legal explicability and ethical unification. Empirical analysis of the functional adaptability of technologies in a real investigative process is of particular importance.

**Keywords:** Institutional Governance, Criminal Justice, Human Rights, Democratic Rights, Social Justice, Rule of Law, Indigenous Rights

## 1. Introduction

The digitalization of public administration and jurisdictional practice requires institutionally agreed mechanisms for implementing digital technologies at the pre-trial stage of criminal proceedings, taking into account regulatory traceability, evidentiary verification, and regulatory compatibility[6,7]. In the context of the transformational challenges of the digital society, the need for cognitive algorithmization of procedures, integration of XAI approaches and convergence of technologies at the pre-trial stage is becoming more urgent[8,9]. The relevance of the research is enhanced by the need to model legal explained architectures to stabilize digital law enforcement in the face of institutional fragmentation and wartime risks[10,11]. At the same time, a number of

[6] ALAZZAM, F. A. F.; SHAKHATREH, H. J. M.; GHARAIBEH, Z. I. Y.; DIDIUK, I.; SYLKIN, O. "Developing an information model for e-commerce platforms: A study on modern socio-economic systems in the context of global digitalization and legal compliance", Ingénierie des systèmes d information, 2023, v. 28, n. 4, pp. 969–974. https://doi.org/10.18280/isi.280417

[7] ANTOSHKINA, V.; SHEVCHENKO, D.; SHCHOKIN, R.; BOIKO, O.; FOKIN, Y. F. "The practice of legal interpretation by judicial authorities in Ukraine: Theoretical and organizational principles", Brazilian Journal of Law International Relations/Relações Internacionais no Mundo, 2023, v. 3, n. 41.

[8] YERMACHENKO, V.; BONDARENKO, D.; AKIMOVA, L.; KARPA, M.; AKIMOV, O.; KALASHNYK, N. "Theory and practice of public management of smart infrastructure in the conditions of the digital society' development: Socio-economic aspects", Economic Affairs (New Delhi), 2023, v. 68, n. 1, pp. 617-633. https://doi.org/10.46852/0424-2513.1.2023.29

[9] HUBANOVA, T.; SHCHOKIN, R.; HUBANOV, O.; ANTONOV, V.; SLOBODIANIUK, P.; PODOLYAKA, S. "Information technologies in improving crime prevention mechanisms in the border regions of southern Ukraine", Journal of Information Technology Management, 2021, v. 13, pp. 75-90. https://doi.org/10.22059/JITM.2021.80738

[10] KUSSAINOV, K.; GONCHARUK, N.; PROKOPENKO, L.; PERSHKO, L.; VYSHNIVSKA, B.; AKIMOV, O. "Anti-corruption management mechanisms and the construction of a security landscape in the financial sector of the EU economic system against the background of challenges to european integration: Implications for artificial intelligence technologies", Economic Affairs (New Delhi), 2023, v. 68, n. 1, pp. 509-521. https://doi.org/10.46852/0424-2513.1.2023.20

[11] SEMENETS-Orlova, I.; KUSHNIR, V.; RODCHENKO, L.; CHERNENKO, I.; DRUZ, O.; RUDENKO, M. "Organizational development and educational changes management in public

critical aspects remained unexplored in earlier studies, in particular: indicator-based and model-based stratification of digital technologies at the pre-trial stage, comparative assessment of their legal traceability, and formalization of the optimal institutionalized case taking into account epistemological validation and procedural integration. The study attempts to fill these gaps.

The academic novelty of the study is the implementation of indicator-based and legal stratification of digital technologies at the pre-trial stage and the formalization of the optimal case (implementation model) of instruments with normative traceability, evidentiary validity, and legal explainability.

The hypothesis of the study is the assumption that the developed indicator-based and model-based stratification method provides relevant identification of the optimal case of digital technologies with the maximum procedural and optimization effect based on normative traceability, evidentiary validation, functional relevance, and institutional integration.

The aim of the study is to formalize an indicator-based and model-based approach to the verification of digital technologies suitable for integration into the procedural mechanisms of the pre-trial stage of criminal proceedings, taking into account legal traceology, evidentiary validity, and normative incorporation. Research objectives: (1) Identify the legal validity and normative explicability of digital technologies at the pre-trial stage of criminal proceedings. (2) Systematize technologies by functional role, level of incorporation, and technological profile. (3) Form an optimal case of digital tools relevant to the pre-trial stage. (4) Verify the optimization effect using the indicator model of procedural efficiency. (5) Develop an implementation model taking into account legal, ethical, and procedural aspects.

## 2. Literature review

A literature review was conducted to systematize the academic concepts of digitalization at the pre-trial stage of criminal proceedings. The results on the algorithmization of investigative procedures, electronic forensics, procedural communication, and regulatory implementation were summarized. The doctrinal and methodological background for further research was formed.

As a starting point, Dlamini et al.[12] established that the pre-trial stage of criminal proceedings are being transformed through the institutionalization of AI, blockchain, 5G, and digital twins. A regulatory and technological gap analysis was conducted. The dependence of digital implementation on the pace of regulatory adaptation and techno-legal coherence was proven.

Continuing this direction, Rusman and Surmeneva[13] established that pre-trial criminal proceedings can be optimized through digitalized mediation and restorative justice procedures. A model for terminating minor criminal cases using an interactive multifunctional portal was proposed. The increase in procedural efficiency, evidentiary transparency, and socio-legal balance was proven.

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sector (case of public administration during war time)", International Journal of Professional Business Review, 2023, v. 8, n. 4, e01699. https://doi.org/10.26668/businessreview/2023.v8i4.1699

[12] DLAMINI, N.; MAMUSHIANE, L.; NKOSI, M.; DLAMINI, S.; RAMABOKA, T. Towards a digitally transformed criminal justice system: A South African case study. CSIR Research Space, 2023. Available at: https://researchspace.csir.co.za/server/api/core/bitstreams/521d1bf1-ffbc-422a-984f-703ee6dec933/content (accessed on 15 November 2025).

[13] RUSMAN, G.; SURMENEVA, S. "Digital tools to facilitate the implementation of mediation in criminal proceedings", Revista Brasileira de Alternative Dispute Resolution-Brazilian Journal of Alternative Dispute Resolution-RBADR, 2023, v. 5, n. 10, pp. 177-203. Available at: https://rbadr.emnuvens.com.br/rbadr/article/view/212 (accessed on 15 November 2025).

In support of the technological effect, Hela et al.[14] demonstrated that the pre-trial stage of criminal proceedings were optimized through the implementation of e-court platforms, electronic archiving, and remote teleconferencing. Algorithmic legal analytics, predictive justice, automated procedural communication systems, and digital evidence verification were integrated. Procedural latency and administrative entropy were proven to be reduced through digital justice.

Developing this approach, Qin and Chen[15] found that Trial Informatization transformed pre-trial proceedings through virtualized interrogations, remote sessions, and digital evidence repositories. Automated procedural communication channels and algorithmic interfaces were integrated. Increased accessibility of justice was proven in the face of risks to legitimacy, autonomy, and deterrence.

From the perspective of algorithmization, Goswami and Goswami[16] demonstrated the digital modernization of the pre-trial stage of criminal proceedings through the implementation of AI-driven procedural orchestration systems. The integration of electronic forensics, digital traceology, and automated evidentiary attribution was documented. Increased efficiency of investigative actions was proven through algorithmic verification and regulatory traceability.

More specifically, Biinazarov et al.[17] found that pre-trial interrogation procedures require systematic digitalization through audio and video recording, polygraph analysis, and Gesell's mirror. A decrease in evidentiary validity was found without mandatory documentation. It was proved that the normative implementation of digital protocols increases procedural objectivity and forensic reliability.

From the penitentiary perspective, Khatun and Kumar[18] found that the integration of AI into pre-trial and penitentiary proceedings provided algorithmic decision-making support and risk-based assessment. The use of predictive models for individualization of punishment and resocialization was recorded. Increased efficiency and fairness of procedures was proven if ethical regulation of algorithms was necessary.

In the regulatory dimension, Stoykova[19] found that the pre-trial stage of criminal proceedings require the implementation of the digital right to procedural accuracy (RPA) in accordance with Art. 6 of the European Convention on Human Rights (ECHR). Safeguards against unreliable digital processing of evidence and the right to access the chain of custody were identified. It was shown that the

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[15] QIN, H.; CHEN, L. "Virtual justice, or justice virtually: Navigating the challenges in China's adoption of virtual criminal justice", Computer Law Security Review, 2025, v. 56, 106112. https://doi.org/10.1016/j.clsr.2025.106112

[16] GOSWAMI, D. P.; GOSWAMI, A. "Virtual justice: The role of technology in transforming criminal administration", SSRN Electronic Journal, 2025. https://doi.org/10.2139/ssrn.5121477

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[18] KHATUN, S.; KUMAR, S. "Strategising algorithm: The prospects and perils of artificial intelligence (AI) in criminal justice reformation", In Security intelligence in the age of AI. Emerald Publishing Limited, 2025, pp. 111–133. https://doi.org/10.1108/978-1-83608-156-220251007

[19] STOYKOVA, R. "A new right to procedural accuracy: A governance model for digital evidence in criminal proceedings", Computer Law Security Review, 2024, v. 55, 106040. https://doi.org/10.1016/j.clsr.2024.106040

normative institutionalization of RPA increases forensic validity and procedural safeguards.

In the area of legal representation, Pivaty[20] found that the digitalization of pre-trial proceedings modifies lawyer-client communication and suspects' access to justice. The impact of virtual hearings and digital communication channels on the effectiveness of the defence was documented. The need for the regulation of legal activities in the context of digitalized criminal proceedings was proven.

Finally, in the transnational context, Buono[21] found that the pre-trial stage of criminal proceedings in the EU is being transformed through the implementation of the e-Evidence Digital Exchange System, cross-border MLA/EIO protocols, and videoconferencing procedures. The digital standardization of evidence flows, the integration of OSINT algorithms, and forensic automation were documented. Increased procedural efficiency, evidentiary verifiability, and regulatory resilience were proven.

The analysis of publications showed that digital technologies have increased the efficiency and evidentiary verifiability of pre-trial procedures through the integration of e-court platforms, algorithmic analytics, OSINT tools, and forensic automation. At the same time, risks to procedural legitimacy and regulatory congruence were identified. The results substantiated the need for further research into the regulatory, organizational, and technological foundations of optimizing investigative actions at the pre-trial stage of criminal proceedings.

## 3. Methods and materials

### 3.1. Research design

The research design consists of the following step-by-step procedure for approaching the research results—Figure 1.

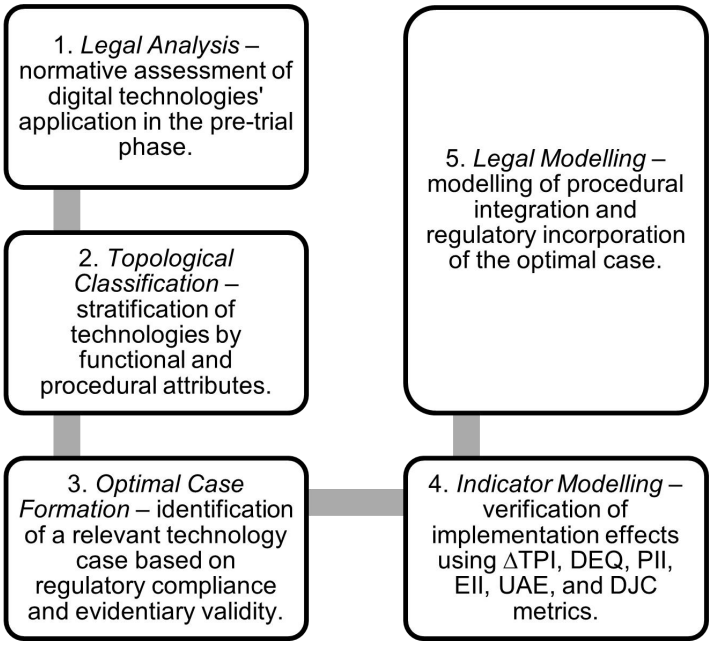


**Figure 1.** Research design. Source: created by the authors.

[20] PIVATY, A. "Lawyers in digitalised criminal proceedings and defendants' access to criminal justice", Tilburg Law Review, 2024, v. 29, n. 2, pp. 31–47. https://doi.org/10.5334/tilr.398

[21] BUONO, L. "Judicial training to prepare criminal justice professionals for #digitalisation and #artificialintelligence", ERA Forum, 2024, v. 25, pp. 159–163. https://doi.org/10.1007/s12027-024-00788-7

### 3.2. Methods

The study applied five complementary methods that ensured a comprehensive multi-level verification of digital technologies in the structure of the pre-trial stage of criminal proceedings:

(1) Legal analysis of norms and regulations. Structural and normative extraction of national and international acts regulating the use of digital technologies at the pre-trial stage of criminal proceedings was carried out. The method identified the legal validity, ethical compatibility, and normative explicability of tools at all stages of the process.

(2) Topological classification of digital technologies. Digital tools were systematized according to the criteria of functional role, technological profile, and level of procedural incorporation. As a result of applying the method, dominant technology clusters—Forensics, AI, Biometrics, e-Evidence Exchange, Video Conferencing—were identified as relevant for the pre-trial stage.

(3) Formalization of the optimal case. An integrated optimal case of digital technologies suitable for implementation in procedural mechanisms of pre-trial investigation was built. The method was based on the criteria of normative legitimacy, evidentiary relevance, and functional integration.

(4) Indicator-based and model-based verification. An assessment of the optimization effect was implemented by modelling the metrics ΔTPI, DEQ, PII, EII, UAE, DJC (Table 2). The method proved a higher level of legal compliance and institutional integration of the technologies of the optimal case, in particular Digital Forensics, AI, Biometrics, e-Evidence Exchange, Video Conferencing.

(5) Legal modelling. A model of the procedural implementation of digital technologies was built taking into account regulatory traceability, ethical unification, and categorical validation. The method revealed high normative integration for key technologies, while outlining the need for additional standardization of Blockchain and Digital Twin/3D.

### 3.3. Sample

The sample of verified digital technologies (Table 1) was formed by systematically stratifying technologies integrated into the pre-trial stage of criminal proceedings in different jurisdictions. The tools with confirmed regulatory implementations, procedural integration, and academic verification were selected. The selection criteria were evidentiary effectiveness, procedural traceability, and techno-legal compliance.

**Table 1.** A selection of verified digital technologies used at the pre-trial stage of criminal proceedings.

| **Digital technology/brief description** | **Mechanisms of use at the pre-trial stage of criminal proceedings** | **Country of implementation/Verified optimization effects** | **Ref.** |
|---|---|---|---|
| *Artificial Intelligence* (algorithmic data processing and predictive analytics) | Automated generation of investigative action protocols, classification of digital evidence, modelling of criminal and legal risks, support for procedural decision-making | USA (2019) /Reducing the time of pre-trial investigation, minimizing subjective errors, increasing evidentiary verifiability | Wani and Mansoor[22], Porfido and Quintavalla[23] |

[22] WANI, S. A.; MANSOOR, S. I. U. "Criminal justice system in the age of artificial intelligence: Exploring rights, risks, and responsibilities in the digital era", Artificial Intelligence in Peace, Justice, and Strong Institutions, 2025, pp. 67–92. https://doi.org/10.4018/979-8-3693-9395-6.ch004

[23] PORFIDO, S.; QUINTAVALLA, A. "Artificial Intelligence and environmental crime", A Research Agenda for Environmental Crime and the Law. Edward Elgar Publishing, 2025, pp. 241–262. https://doi.org/10.4337/9781803929958.00020

| **Digital technology/brief description** | **Mechanisms of use at the pre-trial stage of criminal proceedings** | **Country of implementation/Verified optimization effects** | **Ref.** |
|---|---|---|---|
| *Blockchain* (decentralized data registry) | Fixation of the chain of custody of evidence, registration of procedural actions in chronological order, cryptographic authentication of protocols | Estonia (2020) /Guaranteeing the immutability of evidence, eliminating falsifications, ensuring procedural traceability | Alyas et al.[24], Ramazhamba and Venter[25] |
| *Digital Forensics* (technologies for extracting and analysing digital traces) | Forensic copying of media, recovery of deleted files, analysis of electronic correspondence, inclusion of results in inspection and seizure protocols | UK (2016) /Increasing the accuracy of evidence, expanding the scope of admissible evidence, strengthening the evidentiary base | Raciti and Bella[26], Kuczyńska[27] |
| *Video Conferencing* (secure communication systems) | Conducting remote interrogations and identification, ensuring the right to the participation of a defence attorney, recording judicial control over investigative actions | France (2020) /Acceleration of procedures, reduction of costs, ensuring accessibility of procedural rights | Eagly[28], Mamulai et al.[29] |
| *OSINT* (open source collection and analysis) | Identifying suspects through social networks, documenting public digital data, using secret investigative actions in protocols | Netherlands (2018)/Expansion of the evidentiary base, early detection of criminal patterns, increased analytical capacity | Breuer[30], White[31] |
| *e-Evidence Exchange* (cross-border exchange platforms) | Sending and receiving EIO and MLA requests, electronic legalization of documents, ensuring procedural compatibility between jurisdictions | EU (2021)/Unification of international legal assistance, reduction of procedural latency, increased evidentiary admissibility | Perez[32], Majdoub and Atmani[33] |

[24] ALYAS, T.; ABBAS, Q.; NIAZI, S.; ALQAHTANY, S. S.; ALGHAMDI, T.; ALZAHRANI, A.; ... IBRAHIM, A. M. "Multi blockchain architecture for judicial case management using smart contracts", Scientific Reports, 2025, v. 15, n. 1, 8471. https://doi.org/10.1038/s41598-025-92842-8

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| **Digital technology/brief description** | **Mechanisms of use at the pre-trial stage of criminal proceedings** | **Country of implementation/Verified optimization effects** | **Ref.** |
|---|---|---|---|
| *Biometrics* (automated identification) | Verifying individuals during interrogation, attribution of fingerprints/DNA, identifying witnesses and victims in procedural protocols | India (2017)/Increasing the accuracy of identification, reducing the risk of person substitution, strengthening evidentiary reliability | Kan[34], Nawrocka-Świętkowiak et al.[35] |
| *Polygraph and Neurotechnology* (physiological and cognitive monitoring) | Using interrogation protocols, checking the reliability of testimonies, assessing behavioural reactions in procedural actions | Kazakhstan (2019)/Reducing the risk of distortion of testimony, increasing the objectivity of evidentiary assessment | Okoye and Umeobika[36], Rawat and Tiwari[37] |
| *Digital Twin & 3D Modelling* (virtual event modelling) | Scene reconstruction in inspection protocols, 3D visualization of evidence, recreating the circumstances of the crime | Germany (2021)/Increasing evidentiary visibility, detailing versions, optimizing reconstructive actions | Chango et al.[38], Becker et al.[39] |
| *Predictive Justice* (AI modelling of case outcomes) | Predicting the consequences of procedural decisions, algorithmic assessment of sanctions, analysis of practice when choosing preventive measures | China (2020)/Ensuring procedural consistency, optimizing resources, increasing the efficiency of case management | Wenzelburger et al.[40], Knes et al.[41] |

Source: created by the authors.

### 3.4. Instruments

The research tool stack (Table 2) includes a multi-level system of analytical indicators structured in the areas of procedural efficiency, evidentiary validity, digital traceability and cognitive acceptability. Metric distribution of components and logical-analytical decomposition of variables are used for formalization, normalized formulas with a parametric weight scale. Such a model provides a quantitative explication of the effects of digitalization in the course of investigative actions.

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[34] KAN, C. H. "The examination of neuroscientific evidence in the criminal trial process: The importance of collaboration between criminal law and neuroscience", International Journal of Eurasia Social Sciences/Uluslararasi Avrasya Sosyal Bilimler Dergisi, 2025 v. 16, n. 59, pp. 511–565. https://doi.org/10.70736/ijoess.592

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[40] WENZELBURGER, G.; YEUNG, K.; HARTMANN, K. "Smart justice? Making sense of the rise of algorithm-based pre-trial risk assessment in criminal justice through 'legal models'", Digital Society, 2025, v. 4, n. 2, 48. https://doi.org/10.1007/s44206-025-00194-7

[41] KNES, A. S.; LOWDER, E. M.; THAI, M. L.; REUTER, S. M.; KENT, A. R. "Multi-study examination of criminal-legal professionals' use of risk assessments in pretrial decision-making", Legal and Criminological Psychology, 2025, v. 30, n. 2, pp. 268-297. https://doi.org/10.1111/lcrp.12305

**Table 2.** Indicators of optimization effects from the implementation of digital technologies in procedural mechanisms of pre-trial investigation*,**.

| Indicator | Descriptive formulation | Mathematical formulation |
|---|---|---|
| $\Delta TPI$ (Time Processing Improvement) | Reducing the duration of investigative actions through digitalization | $\Delta TPI = \frac{T_{base} - T_{tech}}{T_{base}} \times 100\%$ where $T_{base}$ —average duration of procedural action without digital technologies; $T_{tech}$ —duration of the same action using technology |
| $DRE$ (Digital Reliability Effect) | The level of reduction in procedural errors when using digital tools | $DRE = \frac{E_{manual} - E_{digital}}{E_{manual}} \times 100\%$ where $E_{manual}$ —error rate in traditional execution of actions; $E_{digital}$—digital error rate |
| $PII$ (Procedural Integrity Index) | Index of preservation of procedural integrity and evidentiary traceability | $PII = \frac{C_{verified}}{C_{total}}$ where $C_{verified}$ —number of checked (verified) links in the chain of custody; $C_{total}$ —total number of chain-of-custody links |
| $DEQ$ (Digital Evidence Quality) | Composite quality of digital evidence | $DEQ = w_1 A + w_2 C + w_3 R$ where $A$ —authenticity; $C$ —integrity; $R$ —relevance; $w_1$, $w_2$, $w_3$ —expert assessment weights |
| $TRF$ (Traceability Factor) | Degree of digital traceability of investigative actions | $TRF = \frac{L_{tracked}}{L_{total}}$ where $L_{tracked}$—number of investigative actions with a confirmed digital trace; $L_{total}$ —total number of actions performed |
| $CRS$ (Cognitive Risk Scoring) | Indicator of cognitive assessment of risk of recurrence/escape | $CRS = \sum_{i=1}^{n} w_i \times r_i$ where $r_i$ —individual risk parameters (e.g., criminal record, escape, connections); $w_i$ — corresponding parameter weights |
| $EII$ (Evidentiary Integration Index) | Level of integration of digital evidence into the system of proceedings | $EII = \frac{D_{integrated}}{D_{available}}$ where $D_{integrated}$ —the number of successfully integrated digital evidence; $D_{available}$ —the total number of collected evidence |
| $DJC$ (Digital Justice Coherence) | Conformity of digital actions with procedural norms | $DJC = \frac{P_{compliant}}{P_{executed}}$ where $P_{compliant}$ —number of actions carried out in compliance with procedural regulations; $P_{compliant}$—total number of digital actions |
| $UAE$ (User Acceptance Effect) | Level of adoption of technologies by investigators, prosecutors, experts | $UAE = \frac{N_{positive}}{N_{total}}$ where $N_{positive}$ —number of entities that supported digital technologies; $N_{total}$ —total number of respondents |
| $PCI$ (Procedural Cost Index) | Reduction in costs of investigative actions due to digitalization | $PCI = \frac{C_{base} - C_{tech}}{C_{base}} \times 100\%$ where $C_{base}$—average cost of actions according to the traditional procedure; $C_{tech}$—the cost of digital technology actions |

Note: *To ensure comparability, the indicators were unified through mathematical normalization using standardized scales. Parametric transformation and linear scalarization were applied to eliminate dimensional heterogeneity. This guaranteed metric compatibility and correctness of further interpretation. ** Intermediate computations and case-level numeric datasets were not reported due to journal constraints on manuscript volume and result presentation density. Accordingly, the indicator system (ΔTPI, DEQ, PII, EII, UAE, DJC) was operationalized as a formal modelling layer for procedural–legal stratification and cross-technology comparability, rather than as a direct empirical test. Empirical instantiation of variables and distributional validation were designated as a subsequent stage of controlled pre-trial implementation assessment. Source: created by the authors.

For indicator-based modelling of optimization effects of implementation of digital technologies in procedural mechanisms of pre-trial investigation, Python

language was used as a basic tool of analytical implementation. NumPy libraries (vectorization and normalization of indicators), Pandas (data structuring), Matplotlib/Seaborn (visualization), SciPy (statistical verification), scikit-learn (regression modelling) were used. Such tool stack provides algorithmic explainability, replicated verification, and analytical integration of results.

## 4. Results

Legal analysis of the norms and provisions regulating the use of digital technologies at the pre-trial stage of criminal proceedings (Table 3) was performed as a basic phase of the study. The purpose of this analysis was to form a normative and doctrinal basis for further procedural and technological stratification. The conducted study provided a systematic identification of the current regulatory structures that determine the algorithms of admissibility of digital evidence, standards of procedural traceability, and forms of legal legitimation of digital instruments. This approach allowed to establish the degree of normative unification, forensic validation, and procedural convergence between leading jurisdictions.

**Table 3.** Legal analysis of the norms and provisions of the use of digital technologies for conducting investigative actions at the pre-trial stage of criminal proceedings*.

| **Country** | **Norm/regulation (exact reference; summary)** | **Permitted digital technologies** | **Impact on procedural mechanisms** | **Known legal process (year; use)** |
|---|---|---|---|---|
| USA | FRE Rule 902(13),(14); Fed. R. Crim. P. 41; 18 U.S.C. §2703 (SCA)—self-certification of electronic records; warrant searches of media; requests to providers | Digital Forensics, e-Evidence, AI, OSINT, Biometrics, Video Conferencing | Simplify authentication; strengthen warrant regime; chain of custody standards | *Riley v. California* (2014); warrantless mobile forensics ruled inadmissible); *Carpenter* (2018); CSLI as evidence under warrant) |
| UK | PACE 1984, Codes B/D/E; Criminal Justice Act 2003, Pt 11—search/seizure; identification; audio recording of interviews; computer evidence regime | Digital Forensics, Biometrics, Video Conferencing, OSINT | Interrogation protocol; presumption of reliability of digital records; admissibility control | *PPS v. Elliott & McKee* (2013); electronic Livescan fingerprint admitted as evidence) |
| EU | Regulation (EU) 2023/1543 (e-Evidence), Dir. 2014/41/EU (EIO)—production/storage orders; cross-border exchange | e-Evidence Exchange, Digital Forensics, Video Conferencing | Forms standardization; latency reduction; procedure compatibility | e-Evidence Implementation Practices in Member States (Use of Electronic Forms in EIO Requests) |
| Germany | StPO §§100a, 100b, 110, 95—interception, online search, search/seizure; §§163, 184 GVG (judicial control) | Digital Forensics, OSINT, Biometrics, Remote Access Tools | Judicial authorization regime; strict chain of custody; proportionality control | BVerfG 1 BvR 370/07 (2008); constitutional limits of "online-Durchsuchung") |
| France | CPP arts. 706-102-1—706-102-9; 230-32 s.—remote intrusion/data copying; metadata analytics | Digital Forensics, Remote Forensic Tools, Video Conferencing | Legalization of "captation de données"; formalization of the chain of custody | Cass. crim. (2021–2022); EncroChat data access, digital attribution and chain) |
| Italy | CPP art. 266-bis, 266-ter, 247-bis; 354—interception of telematic communications; search of IT systems; seizure | Digital Forensics, Captatore Informatico, OSINT | Judicial control over "trojans"; procedural traceability | Cass., Sez. Unite, n. 26889/2016 (captatore; conditions of admissibility of the collected data) |

| Country | Norm/regulation (exact reference; summary) | Permitted digital technologies | Impact on procedural mechanisms | Known legal process (year; use) |
|---|---|---|---|---|
| Spain | LECrim arts. 588 bis a–k; 588 ter—data interception/capture; remote search | Digital Forensics, Remote Search, Video Conferencing | Formalization of warrants for IT systems; evidentiary standards | AN/TS (2020–2022); use of data from messengers/clouds in the pre-trial phase) |
| The Netherlands | Sv art. 125i–125n; 126nba/nd—data access/telematics; preservation; covert investigative actions | Digital Forensics, OSINT, e-Evidence | Extended "vorderingen" to providers; metadata logging | HR 4-4-2017, ECLI:NL:HR:2017:584 (device data disclosure; procedural boundaries) |
| Estonia | KrMS §90¹, §91, §142—digital evidence; data search/seizure; storage | Blockchain (state registers), Digital Forensics, e-Evidence | Integration of e-registries; chain of custody transparency | Practice of Harju/Ringkonnakohus (2018–2022); pre-trial digital extraction) |
| Poland | KPK arts. 217–236, 236a, 218—seizure; dostęp do danych telekom.; Ustawa o policji (operatywка) | Digital Forensics, OSINT, e-Evidence, Biometrics | Formalization of telecom data; NSRD protocol; chain | SN (2014–2021); admissibility of logs/metadata in pre-trial investigation) |
| Canada | Criminal Code ss. 487.014–487.019, 487.0191; 492.1; 487.11; Charter s.8—production/preservation orders; tracking; privacy standards | Digital Forensics, OSINT, e-Evidence, Video Conferencing | Forensic access control; privacy/efficiency balance | R v. Spencer (2014; ISP data request as "search"), R v. Vu (2013); computer = separate warrant) |
| Australia | Crimes Act 1914 s.3LA; TIA Act 1979; Surveillance Devices Act 2004—coercion to provide keys; interception; technical means | Digital Forensics, OSINT, e-Evidence | Decryption by warrant; procedural compatibility | Federal cases (2018–2022); forced key disclosure and forensic images) |
| Japan | CCP arts. 197–222 (spec.), 218 (order), 222-2; Wiretapping Act—warrant searches of IT systems; wiretapping | Digital Forensics, OSINT, Biometrics, Video | Procedural legalization of electronic seizures; chain | Winny case (SC, 2011); analysis of digital traces/logs in the pre-trial phase) |
| South Korea | Criminal Procedure Act art. 215; Protection of Communications Secrets Act—search/extraction of data; interception | Digital Forensics, OSINT, e-Evidence | Judicial authorization for device/cloud data; traceability | Supreme Court (2012–2019); admissibility of messenger logs/telecom metadata) |
| India | Bharatiya Sakshya Adhiniyam (ex-s.65B IEA); CrPC ss. 91, 92—electronic evidence; certificate requirements | Digital Forensics, Biometrics, OSINT, e-Evidence | E-records certification; procedural admissibility | Arjun Panditrao (2020); 65B certificate as a condition for admissibility of e-evidence) |
| Brazillia | CPP arts. 158-A—158-F (Lei 13.964/2019); Marco Civil da Internet, art.10–13—chain of custody; provider data | Digital Forensics, e-Evidence, OSINT | Mandatory "cadeia de custódia"; request standards | STF/STJ (2016–2021); WhatsApp data/telecom metadata in pre-trial investigation) |

Note: *"Pre-trial stage" was used as a functional umbrella for legally regulated investigative activity prior to adjudication; the table compared normative provisions governing digital technology use rather than harmonizing jurisdiction-specific procedural phases or investigative acts. Source: created by the authors.

The results of the legal analysis (Table 3) showed that the most institutionalized and procedurally effective technologies are Digital Forensics, e-Evidence Exchange, OSINT, Biometrics, and Video Conferencing. These technologies provided cognitive

algorithmization of the evidentiary process and optimization of criminal justice mechanisms. Their implementation contributed to increasing the level of procedural interoperability, evidentiary verifiability, as well as regulatory compatibility of transnational procedures. As a result, an analytical basis was formed for the next stage of the study—the topological classification of digital technologies according to their functional and procedural specialization in the system of pre-trial criminal proceedings (Table 4).

**Table 4.** Topological classification of digital technologies used in investigative actions in pre-trial criminal proceedings.

| **Digital technology** | **Functional and procedural specialization** | **Procedural role** | **Level of integration into pre-trial proceedings** |
|---|---|---|---|
| *Evidential identification and verification technologies* | | | |
| Biometrics | Personalized identification of individuals | Identification, verification, comparison | High (AFIS, DNA-DB, Face Recognition) |
| Polygraph and Neurotechnology | Psychophysiological assessment of the reliability of testimonies | Neuropsychological Validation, Screening | Low–medium (depending on jurisdiction) |
| *Remote communication and participation technologies* | | | |
| Video Conferencing | Remote investigation | Video interrogation, virtual identification | High (according to procedural norms) |
| *Digital analysis and forensic reconstruction technologies* | | | |
| Digital Forensics | Extraction, analysis and preservation of digital evidence | Forensic science, attribution | High (ISO/IEC 27037-compliant) |
| Digital Twin & D Modelling | Forensic scenario reconstruction | Spatial event replication, forensic visualization | Medium (Crime Scene Simulation) |
| *Foresight, classification and analytical support technologies* | | | |
| Artificial Intelligence | Analytical data processing, automated profiling | Prognostic analysis, classification, risk scoring | High (Predictive Case Analysis, XAI Tools) |
| Predictive Justice | Algorithmic modelling of future procedural actions | Decision forecasting, risk assessment of recurrence | Low–medium (pilot systems) |
| OSINT | Collection of information from open sources to build evidentiary hypotheses | Information support for investigation, operational analytics | Medium (unformalized evidence base) |
| *Technologies for preservation, traceability and exchange of digital evidence* | | | |
| Blockchain | Technologies for preservation, traceability and exchange of digital evidence | Registration of investigative actions, audit trail, chain-of-custody | Medium (E2E Evidence Traceability) |
| e-Evidence Exchange | Cross-border exchange of digital evidence | Electronic transfer between jurisdictions | High (EPOC, e-CODEX, Eurojust Gateway) |

Source: created by the authors.

Summarizing the provisions of Table 4, Artificial Intelligence, Digital Forensics, e-Evidence Exchange, Biometrics, and Video Conferencing are the most integrated into the structure of pre-trial criminal proceedings. They provide a high level of functional and procedural compliance and regulatory incorporation. Their application covers key stages of investigative actions—from the identification of subjects to the cross-border exchange of evidence. It contributes to the algorithmization of the evidentiary process, spatial reconstruction of events and cognitive support of procedural decisions. This creates a sound basis for forming a case of appropriate digital technologies relevant to the jurisdictional requirements and evidentiary standards of modern criminal proceedings (Table 5).

**Table 5.** Optimal case of digital technologies appropriate for integration into the procedural mechanisms of pre-trial investigation.

| Digital technology | Legal compatibility | Evidential suitability | Functional relevance | Level of integration |
|---|---|---|---|---|
| Digital Forensics | Art. 94, 107–110 КПК; ISO/IEC 27037 | High (authentication, forensics, chain of custody) | Expert attribution of digital artifacts | High (case law, SOPs) |
| Artificial Intelligence | XAI protocols, GDPR Art. 22, ECHR Art. 6 | Medium–high (depending on XAI explainability) | Analytics, profiling, risk scoring | High (Predictive Case Analysis) |
| Biometrics | Art. 107 КПК; GDPR Rec. 51, 75 | High (identification, verification, AFIS/Face/Voice DBs) | Identity verification, digital tracing | High (BKA, FBI, MIA DB) |
| e-Evidence Exchange | Regulation (EU) 2023/1543; Dir. 2014/41/EU | High (standardized requests, EIO forms) | Electronic transfer of evidence between jurisdictions | High (EPOC, e-CODEX) |
| Video Conferencing | Art. 232 КПК; PACE Code D, EU standards | High (interrogation, identification, witness participation) | Remote procedural support | High (ECtHR recognized) |
| Blockchain | Chain-of-custody Technical Standards (NIST) | High (immutability, audit trail, E2E-preservation) | Fixing of investigative actions, protection against falsification | Medium (pilot modules) |
| Digital Twin/3D | Forensic Practice (Crime Scene Imaging) | Medium (visual reconstruction) | Scenario modelling, spatial reconstruction of events | Medium (crime scene simulation) |

Source: created by the authors.

The formation of a case of appropriate digital technologies (Table 5) provided a stratified selection of solutions with the highest level of legal compatibility, evidentiary validity, and functional relevance within the framework of pre-trial criminal proceedings. The core included Digital Forensics, Artificial Intelligence, Biometrics, e-Evidence Exchange, and Video Conferencing—technologies that have regulatory support (CPC, GDPR, ECHR, EU Directives). They are characterized by proven suitability for procedural use (authentication, traceability, video interrogation) and a high degree of integration into investigative practice. The inclusion of Blockchain and Digital Twin/3D as auxiliary elements increases the reconstructive and protective capacity of the case. The next step of the study is indicator-based and model-based verification, aimed at empirically testing the validity of the formed case and confirming its effectiveness in the structure of the pre-trial stage of criminal proceedings (Figure 2).

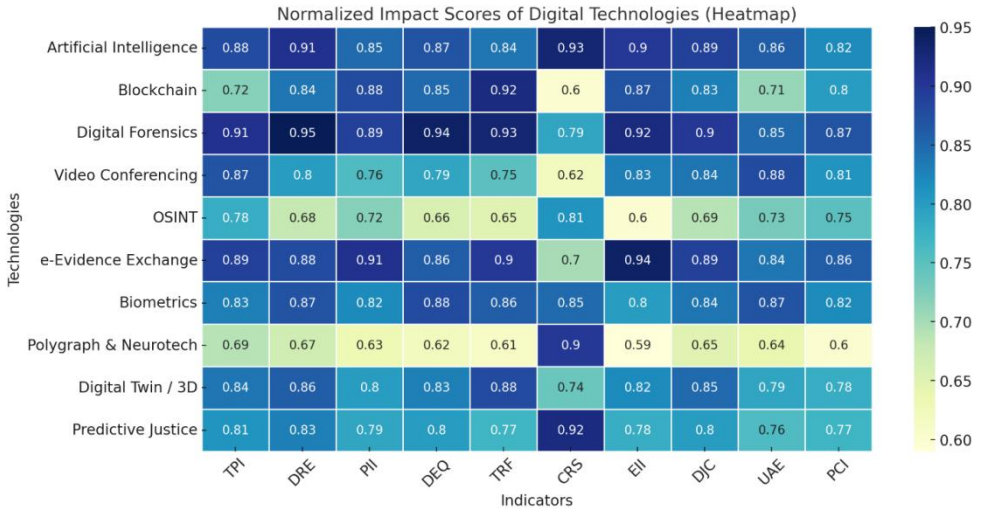


**Figure 2.** Indicator-based and model-based verification of optimization effects from the implementation of digital technologies in procedural mechanisms of pre-trial investigation. Source: created by the authors in Python.

The indicator-based modelling (Figure 2) allowed stratifying digital technologies according to the criteria of procedural expediency, integration relevance, and evidentiary stability. Digital Forensics, Artificial Intelligence, Biometrics, e-Evidence Exchange, Video Conferencing, and Blockchain demonstrated the highest normalized values for the metrics ΔTPI, DEQ, PII, EII, UAE and DJC. This fully correlates with their regulatory compliance, functional adaptability, and degree of institutionalized integration (Table 5). The results justify the need for multi-level legal modelling of the implementation of digital technologies at the pre-trial stage of criminal proceedings. The modelling should take into account the requirements of the Code of Criminal Procedure, GDPR, ECHR, XAI protocols, ISO/IEC standards and transjurisdictional e-CODEX procedures (Table 6, Table 7).

**Table 6.** Legal modelling of the implementation of digital technologies in procedural mechanisms at the pre-trial stage of criminal proceedings.

| **Digital technology** | **Regulatory framework** | **Procedural limits of application** | **Legal restrictions** | **Ethical and legal caveats** | **Necessary implementation conditions** |
|---|---|---|---|---|---|
| Digital Forensics | CPC of Ukraine (Article 94, 107–110), ISO/IEC 27037 | Collection, authentication, expert processing of digital evidence | Chain-of-custody violations; access rights violations | Risk of unlawful extraction of personal data | Laboratory certification; SOP approval; forensic audit |
| Artificial Intelligence | GDPR (Article 22), ECHR (Article 6), XAI protocols | Behavioural pattern analytics, cognitive profiling, predictive scoring | Limitations on automated decision-making without humans; mandatory explainability (XAI) | Discrimination risks, invasion of privacy | Algorithmic explainability; external validation of models; legal expertise |
| Biometrics | CPC of Ukraine 107), GDPR Rec. 51, 75; CJEU Case C-291/12 | Personal identification, comparison with AFIS, FaceDB, VoiceDB databases | Limitations on use without consent; limits on lawful retention | Risks of mass surveillance; invasion of bodily autonomy | Availability of legal basis (e.g., resolution); template encryption; database audit |
| e-Evidence Exchange | Regulation (EU) 2023/1543, Directive 2014/41/EU | Inter-jurisdictional transfer of evidence, e-EIO, requests to providers | Risks of loss of evidentiary value during transnational exchange | Insufficient compatibility of national CCP procedures with e-CODEX | Electronic certification; EPOC formats; multi-jurisdictional agreement |
| Video Conferencing | КПК (Art. 232), PACE Code D, EU Guidelines | Conducting interrogation, identification, investigative experiments remotely | Inability to ensure full confidentiality and authenticity of the environment | Risks of external pressure on the participant; psychological distortions | Technical fixation; identity control; procedural verification of conditions |
| Blockchain | NIST Chain-of-Custody Framework, UNODC Technical Guide | Immutable recording of investigative actions, preservation of digital traces | Lack of regulatory support in national law | Limitations of transparency - risk of privacy violation | Legal recognition of records in the blockchain; access delimitation; audit |
| Digital Twin /3D Modelling | Judicial practice (crime scene reconstruction);Forensic Visualization Guidelines | 3D spatial modelling, reconstruction of events for the court | Limited evidentiary value without additional expert validation | Manipulative effect, cognitive distortions in judges/jurors | Modelling accuracy standards; expert interpretation; accompanying verification act |

Source: created by the authors.

**Table 7.** Comparative matrix of the results of legal modelling of the implementation of digital technologies in procedural mechanisms of the pre-trial stage of criminal proceedings.

| Digital technology | Reg. Base | Proc. Scope | Legal Limits | Ethical Risks | Impl. Conditions |
|---|---|---|---|---|---|
| Digital Forensics | 1 | 1 | 2 | 2 | 1 |
| Artificial Intelligence | 2 | 1 | 2 | 3 | 2 |
| Biometrics | 1 | 1 | 2 | 2 | 1 |
| e-Evidence Exchange | 1 | 1 | 2 | 2 | 1 |
| Video Conferencing | 1 | 1 | 2 | 2 | 1 |
| Blockchain | 2 | 2 | 3 | 2 | 2 |
| Digital Twin /3D | 2 | 2 | 1 | 2 | 2 |
| Key: 1—high relevance; 2—partial relevance; 3—legal risk/restriction | | | | | |

Source: created by the authors.

The results of legal modelling (Table 6, Table 7) showed that Digital Forensics, Biometrics, e-Evidence Exchange, and Video Conferencing have the highest regulatory integration (1 in 4/5 categories) and demonstrate relevance to the main procedural scenarios. At the same time, Artificial Intelligence, Blockchain, and Digital Twin /3D require additional algorithmic explainability and regulatory incorporation. In addition, their ethical and legal unification is necessary in accordance with the principles of XAI, chain-of-custody, and forensically sound visualization. The obtained results confirm the feasibility of phased implementation taking into account the principles of legal traceability, ethical proportionality, and institutional verification of digital technologies in pre-trial proceedings.

## 5. Discussion

The discussion comparison provided an indicative stratification of the obtained results in the context of normative relevance, algorithmic validity and regulatory traceability. The methodological expediency consisted in verifying the level of conceptual coherence with the approved models of digital justice. An epistemological explication of the differences in law enforcement approaches was provided.

Contini[42] found that the fragmented implementation of the ToL and CPO platforms caused normative fragmentation and procedural indeterminacy. In this study, the full institutionalization of Digital Forensics and e-Evidence Exchange ensured legal traceability and functional interoperability. The results are partially correlated, but demonstrate a higher degree of normative coherence.

Wawrzyńczak[43] focused on the interdisciplinary conceptualization of digital justice within comparative legal systems. This study implemented a procedure-centric modelling involving indicator norming and legal traceology. The consistency is general, but the degree of normative detail and algorithmic verification is higher.

Chan and Cabral[44] represented an institutional shift towards AI-determined digital justice, focusing on ODR, online forums, and procedural guarantees. This study was dominated by criminal procedural mechanisms with a priority of

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evidentiary relevance, ethical and legal traceability and XAI verification. The obtained results were only partially correlated—common vectors of institutionalization of digital procedures with significant differences in the evidentiary and legal model.

Borgesano et al.[45] systematized AI innovations in the Justice 5.0 paradigm—predictive justice, cognitive collaboration, robotic justice. In this study, the emphasis is shifted to the incorporation of XAI into pre-trial procedures, taking into account GDPR restrictions and evidentiary relevance. The results are partially correlated, but diverge in terms of the level of regulatory institutionalization and procedural traceability.

Branovitskii[46] demonstrated the destructive effects of LegalTech commodification of law, in particular in terms of procedural deprofessionalization and erosion of normative autonomy. Instead, this study focused on the normative and ethical implementation of XAI and digital technologies within the criminal process. The agreement is limited: the difference is the regulatory integration and the level of procedural legitimation.

Ramos-Maqueda and Chen[47] empirically substantiated the potential of data science in transforming justice through ML analytics and text-as-data methods. This study, in contrast, focused on the procedural implementation of XAI, forensics, and e-Evidence within the framework of regulatory incorporation. Therefore, the results are partially correlated, but differ in the level of procedural detail and legal verification.

Parvatam et al.[48] outlined the potential of DSAI frameworks to improve the efficiency of justice, with an emphasis on local case management. In contrast, this study implemented an indicator model of the legal integration of AI, Forensics, and Blockchain into the procedural mechanisms of pre-trial investigation. Therefore, the results are conceptually consistent, but differ in the level of procedural specification and regulatory coverage.

Kremens and Peristeridou[49] substantiated the risks of reducing procedural presence and digital vulnerability in virtualized criminal proceedings. Instead, this study proved a high degree of procedural incorporation and evidentiary compatibility of videoconferencing at the pre-trial stage of proceedings. Despite partial methodological correlation, the approaches differ: in Kremens and Peristeridou—axiological-normative modelling, in this—indicator-legal stratification of technologies.

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[45] BORGESANO, F.; De MAIO, A.; LAGHI, P.; MUSMANNO, R. "Artificial intelligence and justice: a systematic literature review and future research perspectives on Justice 5.0", European Journal of Innovation Management, 2025, v. 28, n. 11, pp. 349-385. https://doi.org/10.1108/EJIM-01-2025-0117

[46] BRANOVITSKII, K. L. "Artificial intelligence and legaltech: Risks of transforming the legal profession", Digital Law Journal, 2025, v. 5, n. 4, pp. 28–40. https://doi.org/10.38044/2686-9136-2024-5-5

[47] RAMOS-MAQUEDA, M.; CHEN, D. L. "The data revolution in justice", World Development, v. 186, 2025, 106834. https://doi.org/10.1016/j.worlddev.2024.106834

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Wang et al.[50] verified the effectiveness of big data and AI in the administration of judicial processes, focusing on the reconfiguration of trial management. In contrast, this study provides a normative-procedural incorporation of AI, e-Evidence, and Biometrics at the pre-trial stage. The results are partially correlated—with a common principle of digital justice, the level of procedural detail, and the focus of managerial coverage are different.

Flower[51] interpreted the digitalization of justice as a socio-constructive transformation of judicial legitimacy that modifies the perceptual framework of procedural justice. This study, however, focuses on the normative-indicator traceology of XAI, Forensics, and e-Evidence. The results are partially consistent, but differ in the object of regulatory enshrinement.

The comparative analysis demonstrated the superiority of the obtained results in terms of the level of normative traceability, indicator detail, and XAI-verified evidentiality. Differences were found in the level of evidential verification, legal traceology, and regulatory coverage. The obtained results demonstrated a higher degree of functional incorporation of technologies in the pre-trial phase, as well as a higher degree of procedural integration, epistemological explication, and regulatory compatibility within the criminal procedural jurisdiction. So, the research hypothesis is proven, as the proposed indicator-based and model-based stratification method ensured the identification of the optimal case of digital technologies for implementation with the highest level of normative traceability, evidentiary explication, procedural integration, and epistemological validation at the pre-trial stage.

## 6. Limitation

No field testing of digital technologies identified as an optimal case has been carried out. There is no empirical data on their impact on procedural efficiency at the pre-trial stage of criminal proceedings. No integration testing has been carried out under the conditions of the functional workload of investigative bodies. A key limitation was the normative and expert-dependent nature of DJC, PII, and DEQ, which operationalized legal-procedural judgments in quantitative form. The DEQ weights ($w_1$–$w_3$) were parameterized and were not supported by inter-rater reliability testing or standardized calibration. Therefore, these indicators should be interpreted as heuristic modelling instruments, requiring further empirical validation in controlled pre-trial settings. A limitation was the absence of a granular procedural analysis of AI-specific safeguards, including defence contestability of algorithmic outputs, disclosure obligations for models/training data/error rates, and equality-of-arms preservation under pre-trial risk scoring and profiling. The blockchain component was treated at a conceptual level, without empirical validation of ledger governance, access-control regimes, error propagation (GIGO), and the evidentiary admissibility of on-chain records. Consequently, the chain-of-custody implications were not fully operationalized as a legal-institutional construct rather than a purely technical immutability claim.

## 7. Recommendations

[50] WANG, Z.; HUANG, Z.; XIAO, S. "From "non-separation of adjudication and management"to comprehensive platform-based supervision and management: Aligning the development of trial management with judicial fairness and efficiency", In Proceedings of the 2025 2nd International Conference on Innovation Management and Information System. New York, NY, USA: ACM, 2025, pp. 258–266. https://doi.org/10.1145/3745676.3745714

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It is necessary to implement a full-scale verification of the optimal case in pre-trial practice. It is appropriate to conduct a controlled assessment of the impact of digital technologies on the effectiveness of pre-trial procedures. It is necessary to provide an empirical assessment of the functional adaptability of technologies in the investigative process. Future research should operationalize AI-related procedural safeguards in the pre-trial phase by specifying defence contestability protocols, disclosure standards for models/training data/error rates, and equality-of-arms compliance under algorithmic risk scoring and profiling. Controlled validation should further assess the legal robustness, due-process compatibility, and adversarial verifiability of such mechanisms across jurisdictions. Further research should conduct controlled assessment of blockchain-based evidence pipelines, focusing on permissioned governance models, privacy-by-design, auditability, and procedural admissibility thresholds. Particular attention should be given to integrating blockchain records into formal chain-of-custody doctrine, including authentication, integrity verification, and judicial contestability mechanisms.

## 8. Conclusions

The study carried out a comprehensive stratification of digital technologies according to the criteria of institutionalization, procedural efficiency, integrative relevance, and normative incorporation into the pre-trial stage of criminal proceedings. It was found that Digital Forensics, e-Evidence Exchange, OSINT, Biometrics and Video Conferencing are the most institutionalized and provide cognitive algorithmization of the evidentiary process and transnational normative compatibility. Artificial Intelligence, Digital Forensics, e-Evidence Exchange, Biometrics, and Video Conferencing are the most integrated into the pre-trial stage structure. These technologies cover the key stages of the pre-trial investigation and increase the level of procedural algorithmization and normative incorporation.

The core of digital technologies suitable for implementation was formed by Digital Forensics, Artificial Intelligence, Biometrics, e-Evidence Exchange, and Video Conferencing as tools with confirmed regulatory fixation, evidentiary validity and functional relevance; Blockchain and Digital Twin/3D—as auxiliary elements. Indicator-based modelling (Figure 2) confirmed the legal compliance and institutional integration of these tools—by the maximum values of ΔTPI, DEQ, PII, EII, UAE, DJC. According to the results of legal modelling (Tables 6–7), Digital Forensics, Biometrics, e-Evidence Exchange, and Video Conferencing demonstrated the highest regulatory integration (1 in 4/5 categories). At the same time, AI, Blockchain and Digital Twin/3D require additional legal explainability, ethical unification, and procedural implementation. The study is the first to carry out an indicator-based and legal stratification of digital technologies at the pre-trial stage with the formalization of the optimal case of institutionalized tools that ensure regulatory traceability, evidentiary validity, and functional relevance. A model of cognitive-algorithmic implementation of XAI, Forensics, Biometrics, and e-Evidence Exchange was proposed, taking into account legal explainability and regulatory incorporation.

The obtained results form a unified regulatory and technological framework for the integration of digital tools into pre-trial investigation mechanisms. The identified technologies with the highest degree of institutional integration can be the basis for legal implementation, controlled validation of impact, and further regulation in the criminal process.

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