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Digital technologies in the field of migration control in the context of international law

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Abstract: The article presents the results of a comprehensive study of digital technologies in the field of migration control in the context of international law using the examples of Ukraine, Poland, and the United Kingdom (UK). The aim of the study is to comprehensively assess the level of digital integrity and legal balance of migration control systems in Ukraine, Poland, and the UK based on the integration of technical, ethical, legal, and humanitarian parameters using the author's Migration Digital Integrity Index (MDII). The methodological architecture combines comparative legal, statistical, and modelling approaches using Delphi survey, analytical hierarchy process (AHP), correlation and regression analyses (Pearson, Spearman), bootstrap estimation (n = 1000), k-means clustering, and PCA visualization. The results showed that the UK achieves the highest rate of digital integrity (MDII = 0.83) thanks to the legal-by-design legal model, Poland (MDII = 0.77) forms a balanced technological and humanitarian system, and Ukraine (MDII = 0.70) is characterized by high digital activity with lower legal stability. The academic novelty is the creation of a multidimensional tool for quantitative assessment of the legal balance of digital migration control systems. The practical value is identified areas for harmonizing the Ukrainian model with the European standards eIDAS 2.0, GDPR, and OECD Digital Government Framework in order to increase the legitimacy, efficiency, and ethics of migration governance.

Keywords: Digital Governance, Migration Control, Digital Integrity, Legal Reliability, Human Rights, Information Systems

1. Introduction

In the 21st century, digital technologies are becoming a key factor in the transformation of the international migration control system. The transition from paper-based procedures to electronic databases, biometric platforms, and automated verification systems is changing not only the technical means of managing migration flows, but also the very nature of state sovereignty, which is increasingly implemented through algorithmic and cross-border digital tools. This necessitates a review of the traditional legal boundaries of state interference in freedom of movement and personal privacy. The use of digital technologies in the field of migration control combines elements of information security, administrative law, international humanitarian law, and human rights. On the one hand, digitalization increases the efficiency and speed of decision-making, allows identifying the risks of illegal migration, human trafficking or terrorist movements. On the other hand, it generates complex legal conflicts related to personal data processing, algorithmic bias, and extraterritoriality of information flows[6,7,8]. The problematic situation is that the legal regulation of digital migration control mechanisms is developing more slowly than the technologies themselves. Most countries lack uniform standards of ethical and legal responsibility when using algorithms to make decisions on the status of a person, verify documents or identify biometric data. This creates risks of violating human rights, in particular the principles of legality, non-discrimination, and proportionality. Despite the active

[6] BULGAKOVA, I.; GAVEIKA, A.; KRAMPUŽA, I. "Digital Technological and Legal Support of the Illegal Migration Control: A Population and National Security Aspects", In Environment. Technology. Resources. Proceedings of the International Scientific and Practical Conference, v. 5, 2025, pp. 51-56. https://doi.org/10.17770/etr2025vol5.8498

[7] BEDUSCHI, A. "International migration management in the age of artificial intelligence", Migration Studies, v. 9, n. 3, 2021, pp. 576-596. https://doi.org/10.1093/migration/mnaa003

[8] HOLOTA, N. P.; MYKHAILOV, R. I.; MASHTALIR, M. O. "The impact of digitalization on migration processes: Legal aspects", Academic Visions, v. 17, 2023. Available at: https://tesi.luiss.it/39248/1/648522_CASSARO_BIANCA.pdf (accessed on 22 October 2025).

implementation of digital solutions within the framework of EU programmes (eIDAS 2.0, GDPR, Interoperability Framework), the academic literature mainly focuses on technical or ethical aspects, leaving out an integrated assessment of the legal balance of digital migration management systems. This research is intended to fill this gap. Its motivation is based on the need to combine the legal, technological and humanitarian dimensions of digital migration policy in order to assess the extent to which national models provide a balance between the efficiency of public administration and the protection of human rights. The experiences of Ukraine, Poland and the United Kingdom are illustrative for such an analysis, as these countries demonstrate different levels of digital maturity, regulatory coherence, and institutional accountability. The results of the study have practical significance for government structures, politicians, international organizations and scholars working in the field of digital governance, migration policy, and personal data protection. They can be used to develop state strategies for digital management of migration processes, improve interstate cooperation, create mechanisms for algorithmic audit and harmonization of national legislation with the European legal framework.

So, the relevance of the research is the need for an academically grounded assessment of the integrity of digital migration control systems, identifying areas for increasing their legal stability, and forming a model of balancing between technological efficiency and the principles of the rule of law in the context of global digital transformation.

The aim of the research is to comprehensively assess the level of digital integrity and legal balance of migration control systems in Ukraine, Poland, and the UK based on the integration of technical, ethical, legal, and humanitarian parameters within the framework of the author's Migration Digital Integrity Index (MDII).

The aim involves the fulfilment of the following research objectives: (1) Analyse international and national regulatory acts that define the legal framework of digital technologies in the field of migration control, identifying the degree of their harmonization with international standards. (2) Develop and test the author's methodology for quantitative assessment of digital integrity—Migration Digital Integrity Index (MDII), which combines technical, legal, ethical, and humanitarian components. (3) Conduct a scenario analysis of the functioning of digital migration control systems in three countries (primary e-identification, interagency exchange, automated decision-making) to determine their compliance with international legal principles of legality and protection of human rights. (4) Perform a correlation and cluster analysis of the relationship between the MDII index and the EGDI, DESI, and Rule of Law Index in order to identify the impact of international legal standards on the digital stability of state systems. (5) Test the reliability and sensitivity of the MDII index using bootstrap modelling, assessing the stability of country rankings and the impact of weighting factors.

The academic hypothesis of the study is that the integration of digital technologies of migration control into the legal field of international law ensures increased efficiency and trust in state digital systems based on the rule of law, transparency, accountability, and of human rights protection. The optimal combination of technological effectiveness with legal stability creates the basis for the formation of a balanced model of digital governance in the field of migration, consistent with the international obligations of states.

2. Literature review

In recent years, the digitization of migration policy has been increasingly discussed in the academic discourse not only as an act of technical modernization of public administration, but as an act that also constitutes an emergent new dimension of sovereignty, law and humanitarian policy. Researchers are also very

different in their assessments of impacts on human rights and the rule of law. Witteborn[9] and McAuliffe et al.[10] emphasize that digital instruments as part of the migration management reshape the state-individual relations of power itself. They explain that in their conceptualization, digitalization creates a "new data bureaucracy," where algorithmic systems are replacing the discretionary decision-making of the institution on a large scale. This point aligns with security-oriented analyses embedded in the Baltic legal literature, which studies digital governance as a part of public security and border management. More specifically, according to Tumalavičius and Greičius[11] the current border security model depends on integrated decision-making architectures that integrate legal authority, risk assessment, and technological instruments, fundamentally reorienting existing understandings of territorial sovereignty. Part of this thesis is justified by Frowd[12], who looks at the International Organization for Migration and considers this activity as a case of the global centralization of migration data which transgresses classical legal jurisdictions. At the same time, Bellanova et al.[13] rejected technological determinism and proposed that European digital sovereignty is best understood as a balancing act between security, accountability, and the rule of law. Similar concerns emerge in terms of Baltic legal studies of extraordinary governance situations, where algorithmic decision-making may exacerbate legal uncertainty. Načiščionis et al.[14], however, argue that in critical or unexpected situations, relying on automated or data-driven systems needs additional legal certainty to ensure that no individual rights would be disproportionately restricted, in emergencies or unforeseen circumstances. The connection between technological efficiency and humanitarian responsibility is also seen differently by different researchers. Bartolomei and Cava[15] elaborately define the notion of digital humanism, and called for their digitalizing the state system towards promoting both automation and an effective protection of human rights. In contrast, Goldner Lang[16] describes a move towards a security-oriented model in migration governance, in which technology becomes more of a driver of control than protection. This position is critically challenged by Nedelcu and Soysüren's[17] analysis of digital migration systems as

[9] WITTEBORN, S. "Digital placemaking and the datafication of forced migrants", Convergence, v. 27, n. 3, 2021, pp. 637-648. https://doi.org/10.1177/13548565211003876

[10] McAULIFFE, M.; BLOWER, J.; BEDUSCHI, A. "Digitalization and artificial intelligence in migration and mobility: Transnational implications of the COVID-19 pandemic", Societies, v. 11, n. 4, 2021, p. 135. https://doi.org/10.3390/soc11040135

[11] TUMALAVIČIUS, V.; GREIČIUS, S. "Decision making of the ensuring public security at the level of the state territorial borders", Journal of Security and Sustainability Issues, v. 7, n. 1, 2017, pp. 27–38. https://doi.org/10.9770/jssi.2017.7.1(3)

[12] FROWD, P. M. "The 'datafication' of borders in global context: The role of the International Organization for Migration", Geopolitics, v. 30, n. 4, 2025, pp. 1635-1653. https://doi.org/10.1080/14650045.2024.2318580

[13] BELLANOVA, R.; CARRAPICO, H.; DUEZ, D. "Digital/sovereignty and European security integration: an introduction", European security, v. 31, n. 3, 2022, pp. 337-355. https://doi.org/10.1080/09662839.2022.2101887

[14] NAČIŠČIONIS, J.; TUMALAVIČIUS, V.; SKRASTIŅA, U.; RADZEVIČS, J.; PRAKAPIENĖ, D. "Legal consequences of determining unforeseeable extraordinary events", Journal of Security and Sustainability Issues, v. 9, n. 3, 2020, pp. 1117–1127. https://doi.org/10.9770/jssi.2020.9.3(34)

[15] BARTOLOMEI, M. R.; CAVA, A. "Vulnerability, digital technologies and international law: Reflections on contemporary migration flows", Law, Technology and Humans, v. 6, n. 2, 2024, pp. 16-28. https://doi.org/10.5204/lthj.3310

[16] GOLDNER LANG, I. "Security-centric approach in the use of digital technologies in EU migration and asylum policies", Transnational legal theory, v. 15, n. 4, 2024, pp. 591-599. https://doi.org/10.1080/20414005.2024.2399934

[17] NEDELCU, M.; SOYSÜREN, I. "Precarious migrants, migration regimes and digital technologies: the empowerment-control nexus", Journal of Ethnic and Migration Studies, v.

systems of empowerment–control, which point out that digital migration systems can increase migrants' autonomy while they also become more intertwined with state technologies. Seen this way, digital infrastructures have both protective and exclusionary dimensions based on their legal and ethical configuration. Leese et al.[18] further solidify this critical discourse by showing that today EU migration governance largely functions as a data flow management of which the architecture of databases like EURODAC and ETIAS constitute a governing mechanism for legal status. This trend is further highlighted by Bircan and Korkmaz[19] as well as by Frowd[20], who ask whether big data primarily serves security concerns or becomes a means towards technological domination over migrants. These issues echo the wider Baltic scholarship on digital integrity and national security. Makarenkov and Kosa[21], examining the nexus of digital technologies with corruption and national security, warn that greater technological efficiency without corresponding legal and ethical safeguards will not only destroy institutional trust but also accountability. National case studies further illustrate these dynamics. Kortukova[22] points out Ukraine's speed in digital embedding of migration registries within the Diia ecosystem, in contrast with fragmented legislation and weak independent governance of algorithms. Poland is a human-centered digital model, it provides temporary protection through digital tags like PESEL UKR and Diia.pl, in accordance with Directive 2001/55/EC. On the other hand, UK adopted a digital-only immigration status model following Brexit, which has become highly automated, but which in the case of algorithmic error, results in a widening of the access-to-justice concern[23]. From a larger European point of view, Bileviciute[24] points out that a requirement to avoid inconsistencies, ensure accountability and trust between the different national governments in transnational digital governance systems, including those in the migration area, are the legal harmonization and common regulatory standards. And this is a dichotomy evident in contemporary scholarly thought: a techno-institutional logic that stresses security and managerial efficiency, whereas, a humanitarian-legal ethos that makes data ethics, accountability and human rights protection a priority. At the same time, there is a major research gap.

48, n. 8, 2022, pp. 1821-1837. https://doi.org/10.1080/1369183X.2020.1796263

[18] LEESE, M.; NOORI, S.; SCHEEL, S. "Data matters: The politics and practices of digital border and migration management", Geopolitics, v. 27, n. 1, 2022, pp. 5-25. https://doi.org/10.1080/14650045.2021.1940538

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[20] FROWD, P. M. "The 'datafication' of borders in global context: The role of the International Organization for Migration". 2025. Ibid.

[21] MAKARENKOV, O.; KOSA, V. "Forensic technique for identifying corruption challenges to national security through digital technologies", Baltic Journal of Economic Studies, v. 10, n. 4, 2024, pp. 288–300. https://doi.org/10.30525/2256-0742/2024-10-4-288-300

[22] KORTUKOVA, T.; KOLOSOVSKYI, Y.; KOROLCHUK, O. L.; SHCHOKIN, R.; VOLKOV, A. S. "Peculiarities of the legal regulation of temporary protection in the European Union in the context of the aggressive war of the Russian Federation against Ukraine", International Journal for the Semiotics of Law, v. 36, n. 2, 2023, pp. 667–678. https://doi.org/10.1007/s11196-022-09945-y

[23] GOLDNER LANG, I. "Security-centric approach in the use of digital technologies in EU migration and asylum policies". 2024. Ibid.

[24] BILEVICIUTE, E. "Harmonization of application of special knowledge legal regulation creating the common European forensic science space", In Political sciences, law, finance, economics and tourism: Conference proceedings (Vol. I, pp. 569–576). STEF92 Technology Ltd, 2015. Available at: https://cris.mruni.eu/cris/handle/007/31032 (accessed on 21 May 2025).

As noted by Sabie et al.[25] and Connolly et al.[26], quantitative instruments for assessing the integrity and legal balance of digital migration control systems are largely missing. Current work consists largely of normative or descriptive case studies and the integrated empirical models, in which technical/legal/humanitarian dimensions combine underdeveloped. Our study seeks to fill this gap, combining legal, statistical, and modelling analysis using the author's MDII for a comparative assessment of the digital integrity and legality of migration control systems in Ukraine, Poland, and the UK.

Beyond these emerging fields of scholarship, the legal analysis of digital migration control regimes also draws on doctrine. As J. Hathaway (2021)[27] indicates, these doctrines concern the states' exercisable rights and duties, which limit the exercise of administrative discretion and require individual consideration on the basis of due process. Accordingly, the legality of any regime for the control of migration, whether analogue or digital, is not assessed in terms of regulatory compliance alone, but in terms of the protection of these values, and the right to an effective remedy. Relatedly et al.[28] have emphasized that the determination of refugee status is a rights-based adjudicative process that must be governed by the principles of proportionality and evidence, with a safeguard against arbitrary exclusion.

McAdam[29], in her development of this doctrine of complementary protection, makes the point that states' sovereign prerogative to regulate migration is bound by law to their international human rights obligations, in particular where there is a risk of harm. This doctrinal insight is relevant to the determination of automated and algorithmic migration decisions because algorithmic governance does not preclude the need for individual assessments and procedural safeguards.

From the perspective of administrative law and algorithmic governance, Bovens and Zouridis[30] demonstrate that digitization relocates administrative discretion from "street-level" to "system-level" bureaucracy, with negative implications for transparency and accountability. These implications are also highlighted by Kroll et al.[31], who argue that algorithmic decisions must be subject to auditability, reviewability, and contestability if they are to remain rule-of-law compliant.

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[25] SABIE, D.; EKMEKCIOGLU, C.; AHMED, S. I. "A decade of international migration research in HCI: Overview, challenges, ethics, impact, and future directions", ACM Transactions on Computer-Human Interaction (TOCHI), v. 29, n. 4, 2022, pp. 1-35. https://doi.org/10.1145/3490555

[26] CONNOLLY, D.; NAM, S.; GOODMAN, K. "Solving old problems or making new ones? Blockchain technology for the protection of refugees and migrants", Journal of Human Rights, v. 22, n. 2, 2023, pp. 109-134. https://doi.org/10.1080/14754835.2022.2100984

[27] HATHAWAY, J. C. "The Rights of Refugees under International Law", 2nd ed., Cambridge University Press, Cambridge, 2021. https://doi.org/10.1017/9781108863537

[28] HATHAWAY, J. C.; FOSTER, M. "The Law of Refugee Status", 2nd ed., Cambridge University Press, Cambridge, 2014. https://www.cambridge.org/core/books/law-of-refugee-status/2E4AE6854731D8E7184ACD6B0F4FE019

[29] MCADAM, J. "Complementary Protection in International Refugee Law", Oxford University Press, Oxford, 2007. https://global.oup.com/academic/product/complementary-protection-in-international-refugee-law-9780199203062

[30] BOVENS, M.; ZOURIDIS, S. "From Street-Level to System-Level Bureaucracies: How Information and Communication Technology Is Transforming Administrative Discretion and Constitutional Control", Public Administration Review, v. 62, n. 2, 2002, pp. 174–184. https://onlinelibrary.wiley.com/doi/10.1111/0033-3352.00168

[31] KROLL, J. A.; HUEY, J.; BAROCAS, S.; FELTEN, E. W.; REIDENBERG, J. R.; ROBINSON, D. G.; YU, H. "Accountable Algorithms", University of Pennsylvania Law Review, v. 165, n. 3, 2017, pp. 633–705. Available at: https://www.jkroll.com/papers/dissertation.pdf (accessed on 21 May 2025).

Pasquale[32], too, warns that "black box" decision-making processes pose a substantial risk to justice even where formal legality is observed.

From a human rights law perspective, Bovens and Zouridis[33] propose that the accountability of algorithms can be assessed according to existing human rights frameworks on transparency, equality and effective remedy. These theoretical forays reinforce the assumption in the current study that digital migration governance cannot be assessed in exclusively technical terms, but must be evaluated according to a coherent framework grounded in doctrines that strike a balance between sovereignty and discretion, proportionality and procedural fairness. The MDII is, accordingly, doctrinally situated at this crossroads, transforming these normative considerations into quantifiable institutional variables.

3. Problem statement

Digitalization of migration control is becoming a key direction of transformation of state security, combining electronic identification, biometric databases and analytical systems based on artificial intelligence (AI). Such technologies increase the efficiency of response to crisis migration flows, while creating legal conflicts regarding the legality of personal data processing, transparency of algorithms, and observance of human rights[34,35]. The growing role of datafication–the transformation of a person into a digital set of data–reduces the level of individual autonomy and calls into question the balance between security and freedom of movement[36,37]. In the EU, this is manifested through a security-centric approach to digital control systems (EURODAC, ETIAS), which, according to Goldner Lang[38] and Leese et al.[39], actually forms a "data policy", where the information infrastructure determines the limits of the law. A comparative analysis of national approaches shows the fragmentation of technical and legal models. In Ukraine, digital migration management tools are integrated into the Diia system, but there is a lack of a coherent regulatory framework for automated data processing and exchange[40,41,42].

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[32] PASQUALE, F. "The Black Box Society: The Secret Algorithms That Control Money and Information", Harvard University Press, Cambridge, 2015. https://www.hup.harvard.edu/books/9780674970847

[33] BOVENS, M.; ZOURIDIS, S. "From Street-Level to System-Level Bureaucracies: How Information and Communication Technology Is Transforming Administrative Discretion and Constitutional Control". 2002. Ibid.

[34] BARTOLOMEI, M. R.; CAVA, A. "Vulnerability, digital technologies and international law: Reflections on contemporary migration flows". 2024. Ibid.

[35] GOLDNER Lang, I. "Security-centric approach in the use of digital technologies in EU migration and asylum policies". 2024. Ibid.

[36] FROWD, P. M. "The 'Datafication' of Borders in Global Context: The Role of The International Organization for Migration". 2025. Ibid.

[37] WITTEBORN, S. "Digital placemaking and the datafication of forced migrants". 2021. Ibid.

[38] GOLDNER Lang, I. "Security-centric approach in the use of digital technologies in EU migration and asylum policies". 2024. Ibid.

[39] LEESE, M.; NOORI, S.; SCHEEL, S. "Data matters: The politics and practices of digital border and migration management". 2022. Ibid.

[40] KORTUKOVA, T.; KOLOSOVSKYI, Y.; KOROLCHUK, O. L.; SHCHOKIN, R.; VOLKOV, A. S. "Peculiarities of the legal regulation of temporary protection in the European Union in the context of the aggressive war of the Russian Federation against Ukraine". 2023. Ibid.

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Poland has introduced PESEL UKR and Diia.pl, which provide rapid identification of refugees, but create issues of data storage and transfer between registries[43,44]. The UK, developing a digital-only immigration status model, has achieved high automation, but has faced risks of algorithmic discrimination and the lack of effective judicial control[45,46,47]. So, the main problem of the study is the lack of a balanced technical and legal model that can ensure the effectiveness of digital migration control, its interoperability, and compliance with international legal standards of proportionality, legality, and protection of human rights.

To narrow the specification of the identified imbalance, the present analysis works at two levels of analysis. At an empirical level, the "lack of a balanced technical and legal model" refers to a visible lack of symmetry in the present case studies, in which the technical developments are not necessarily balanced by developments in safeguards, transparency or institutionally accountable use. At a normative level, however, the asymmetry also refers to a structural lack of balance that is characteristic of the digital migration governance today, in which the technical developments in automation, interoperability and scalability are not matched by similar developments in consolidating and implementing legally-enforceable safeguards.

The assumption is not that an ideal symmetry between technology and law can always be achieved. Rather, it is understood as a contextual goal of regulatory practice, varying with state capacity, legal culture and the political context. In addition, the areas in which symmetry is lacking are not conflated but analytically distinguished as: (1) legislative, or the lack of clearly defined or complete norms; (2) regulatory incoherence, or fragmentation caused by overlapping regulatory frameworks; (3) enforcement and implementation limits, or institutional capacity issues; and (4) structural issues in algorithmic governance, or such as opacity and distributed accountability. This distinction ensures that no doctrinal issue is confused with operational issues, and improves the analytical accuracy of the problem definition.

4. Proposed methodology

4.1. Research design

[42] 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, v. 13, 2021, pp. 75–90. Available at: https://scispace.com/pdf/information-technologies-in-improving-crime-prevention-5eh5g6z2hh.pdf (accessed on 21 May 2025).

[43] MATUSIAK, J.; NAROŻNIAK, A. "Diia. pl: Navigating legal, technological and human rights dimensions of an electronic document for Ukrainian citizens in Poland", Smart Cities and Regional Development (SCRD) Journal, v. 9, n. 2, 2025, pp. 15-30. https://www.ceeol.com/search/article-detail?id=1323058

[44] ŁYSIENIA, M. "Following the EU response to the Russian invasion of Ukraine? The implementation of the temporary protection directive in Poland", Central and Eastern European Migration Review, v. 12, n. 1, 2023, pp. 183-200. https://doi.org/10.54667/ceemr.2023.14

[45] KOSIEL-PAJĄK, M. "UK border digitalisation–a commentary on the current state of affairs", Applied Cybersecurity Internet Governance, v. 1, n. 1, 2022, pp. 1–6. https://doi.org/10.5604/01.3001.0016.1052.

[46] JABLONOWSKI, K. "Societies of immigration control: the transactional subject of British borders after Brexit", Journal of Ethnic and Migration Studies, v. 51, n. 14, 2025, pp. 3610-3628. https://doi.org/10.1080/1369183X.2025.2513158

[47] PONZANESI, S.; LEURS, K. "Digital migration practices and the everyday", Communication, Culture and Critique, v. 15, n. 2, 2022, pp. 103-121. https://doi.org/10.1093/ccc/tcac016

The methodological architecture of the study is based on a combination of comparative legal, digital analytical, normative, and index approaches aimed at identifying the level of technical and legal balance of migration control systems in Ukraine, Poland, and the UK. This combination of methods enabled integrating the legal and technological dimensions of the functioning of state platforms that identify, monitor, and manage migration flows in the face of increased security risk.

The first stage involved a regulatory audit of digital acts regulating migration processes and the use of personal data in these states. For Ukraine, the Law of Ukraine "On the Unified State Demographic Register…"[48] and the Law of Ukraine "On Electronic Public Services"[49] were analysed, which determine the legal basis for electronic identification of citizens and the functioning of the Diia digital platform. The Polish legal framework is presented in the Ustawa z dnia 12 marca 2022 r. o pomocy obywatelom Ukrainy[50] and the official notification of the MSWiA on the implementation of the digital document Diia.pl[51]. This creates the institutional foundations for the electronic registration of refugees and the integration of databases within the PESEL UKR system. For the UK, the Data Protection and Digital Information Bill[52] and the Nationality and Borders Act 2022[53] were examined, which introduce a "digital-only immigration status" model and determine the procedure for processing biometric and behavioural data in Home Office systems.

The second stage was functional and analytical modelling of the interaction processes of state systems carried out in three typical scenarios: initial digital identification of migrants; interagency data exchange between registries; automated decision-making on status, permit or deportation. Each scenario was evaluated according to the parameters of Digital Performance, Data Ethics & Transparency, Legal Robustness and Human-Centric Resilience, which form the basis of the MDII proposed by the author. The comparison was carried out within a single legal framework formed on the basis of Regulation (EU) 2024/1183 (eIDAS 2.0)[54], Regulation (EU) 2016/679 (GDPR)[55], Global Compact for Migration[56],

[48] Verkhovna Rada of Ukraine. Law of Ukraine "On the Unified State Demographic Register and Documents Confirming the Citizenship of Ukraine" (as amended), 2024. Available at: https://zakon.rada.gov.ua/laws/show/5492-17 (accessed on 21 May 2025).

[49] Verkhovna Rada of Ukraine. Law of Ukraine "On Electronic Public Services" No. 1689-IX (with amendments), 2023. Available at: https://zakon.rada.gov.ua/laws/show/1689-20 (accessed on 21 May 2025).

[50] Sejm of the Republic of Poland. Ustawa z dnia 12 marca 2022 r. o pomocy obywatelom Ukrainy [Act on Assistance to Citizens of Ukraine] (consolidated version with 2024 amendments), 2024. Available at: https://ukraina.interwencjaprawna.pl/the-act-on-assistance-for-ukrainian-citizens/ (accessed on 21 May 2025).

[51] Ministerstwo Spraw Wewnętrznych i Administracji. Diia.pl – elektroniczny dokument dla uchodźców wojennych z Ukrainy, 2022. Available at: https://www.gov.pl/web/udsc/diiapl--elektroniczny-dokument-dla-uchodzcow-wojennych-z-ukrainy (accessed on 21 May 2025).

[52] United Kingdom. Data Protection and Digital Information Bill. London: UK Parliament, 2024. Available at: https://bills.parliament.uk/bills/3322 (accessed on 21 May 2025).

[53] United Kingdom. Nationality and Borders Act 2022. London: UK Government, 2022. Available at: https://www.legislation.gov.uk/ukpga/2022/36 (accessed on 21 May 2025).

[54] European Union. "Regulation (EU) 2024/1183 of the European Parliament and of the Council of 11 April 2024 on digital identity (eIDAS 2.0)", Official Journal of the European Union L 2024/1183, 2024. Available at: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32024R1183 (accessed on 21 May 2025).

[55] European Union. "Regulation (EU) 2016/679 of the European Parliament and of the Council of 27 April 2016 on the protection of natural persons with regard to the processing of personal data and on the free movement of such data (General Data Protection Regulation – GDPR)", Official Journal of the European Union L 119, 2016. Available at: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32016R0679 (accessed on 21 May 2025).

[56] United Nations. Global Compact for Safe, Orderly and Regular Migration. New York: United Nations, 2018. Available at: https://www.iom.int/global-compact-migration (accessed on 21 May 2025).

Recommendation CM/Rec(2021)8 Council of Europe[57], and OECD Government at a Glance 2025[58].

The third stage included a comparative index assessment of the level of digital efficiency, legal compliance, and humanitarian legitimacy of each of the national models. This made it possible to quantify how well technological efficiency and compliance with the international legal principles of proportionality, legality, and accountability are balanced.

The cases of Ukraine, Poland, and the United Kingdom have been selected as a typical analytical and institutionally diverse sample rather than a representative statistical sample. The three cases display a diverse constellation of digital migration governance: a reform-accelerated model of digitalisation (Ukraine), an integrated humanitarian–technological model relying on emergency protection law (Poland), and a lawfully engineered regulatory model featuring a highly institutionalised legal framework (United Kingdom). The jurisdictions are made comparable through a controlled comparison strategy that employs the same scenarios (S1–S3), the same MDII dimensions (DP, DET, LR, HCR) and a single set of reference norms (GDPR, eIDAS 2.0, Council of Europe CM/Rec(2021)8, Global Compact for Migration, OECD Government at a Glance).

4.2. Evaluation metrics

The effectiveness of digital tools in the field of migration control was assessed using the author's MDII, which allows measuring the balance between technological effectiveness, legal compliance, and humanitarian orientation of national systems. Four basic parameters were identified under this approach, covering the technical, legal, and ethical aspects of digital governance (Table 1).

The MDII index integrates four dimensions–technical, ethical, legal, and humanitarian–and reflects the level of "digital integrity" of state migration control systems. The DP indicates the degree of digitalization of procedures and the quality of technical interaction between databases. The DET component captures the level of algorithmic transparency and availability of information for independent audit. The LR indicator assesses the extent to which processes are consistent with European and national data protection standards. The HCR demonstrates the effectiveness of legal and procedural means of protecting migrants. The final index was calculated according to the formula (1):

$$\mathrm{MDII} = (0.35 \times \mathrm{DP}) + (0.25 \times \mathrm{DET}) + (0.25 \times \mathrm{LR}) + (0.15 \times \mathrm{HCR}) \quad (1)$$

Operationally, scores are normalized to 0–1 according to a rubric that is applied uniformly to all countries and scenarios. The scoring includes (1) qualitative coding of the legality/policy of texts against criteria (safeguard present, clear, enforceable?), (2) scenario-relevant coding of procedural checks for S1–S3 (points for paperwork, auditability, contestability), and (3) expert judgement (Delphi rounds). Where available, these include comparable indicators in the public domain. The 0–1 normalization is therefore not 'perceptual' in an arbitrary sense, but a criterion-based 'perception' synthesis in a controlled comparative approach.

[57] Council of Europe. Recommendation CM/Rec(2021)8 of the Committee of Ministers to member States on the impacts of algorithmic systems on human rights. Strasbourg: Council of Europe, 2021. Available at: https://rm.coe.int/0900001680a46147 (accessed on 21 May 2025).

[58] Organisation for Economic Co-operation and Development (OECD). Government at a glance 2025: Full report. OECD Publishing, 2025. Available at: https://www.oecd.org/en/publications/government-at-a-glance-2025_0efd0bcd-en/full-report.html (accessed on 21 May 2025).

Table 1. Metrics for assessing digital migration control systems.

Parameter	Designation	Calculation method	Range	Interpretation
Technological performance	DP (Digital Performance)	The proportion of digital migration control procedures that operate smoothly and ensure interoperability between systems	0–1	Responsiveness and technical stability
Ethics and data transparency	DET (Data Ethics & Transparency)	The level of openness of algorithms, public documentation, availability of external audit or mechanisms for checking algorithms	0–1	Openness, accountability, and trust
Legal reliability	LR (Legal Robustness)	The degree of compliance of procedures with the requirements of GDPR[59], eIDAS 2.0[60], Data Bill (UK)[61] and other acts	0–1	Legality and regulatory coherence
Humanitarian sustainability	HCR (Human-Centric Resilience)	The number and availability of effective mechanisms for appeal, judicial protection and legal monitoring	0–1	Human rights protection and ethical safety

Source: developed by the author based on Regulation (EU) 2024/1183 (eIDAS 2.0)[62], Regulation (EU) 2016/679 (GDPR)[63], Global Compact for Migration[64], Council of Europe Recommendation CM/Rec(2021)8[65], and OECD Government at a Glance 2025[66].

The weighting factors for the MDII were determined by experts based on a multi-level survey conducted between January and September 2025 among 30 highly qualified specialists from three countries–Ukraine, Poland, and the UK. The general population consisted of experts in digital governance and migration policy of European countries. A total of 30 specialists from Ukraine, Poland, and the UK–countries representing a reformist, humanitarian-balanced, and legal model of digital migration control, were selected using a targeted method. They were invited to participate through personal electronic invitations. The number of 30 experts was determined taking into account the principle of representative balance, which ensures both depth and statistical reliability of the results. In general, 10 specialists were selected from each country–Ukraine, Poland, and the UK–to ensure equal representation of administrative-legal, technological, and humanitarian perspectives. This distribution allowed achieving a balance between specialization and statistical

[59] European Union. "Regulation (EU) 2016/679 of the European Parliament and of the Council of 27 April 2016 on the protection of natural persons with regard to the processing of personal data and on the free movement of such data (General Data Protection Regulation – GDPR)". 2016. Ibid.
[60] European Union. "Regulation (EU) 2024/1183 of the European Parliament and of the Council of 11 April 2024 on digital identity (eIDAS 2.0)". 2024. Ibid.
[61] United Kingdom. Data Protection and Digital Information Bill. 2024. Ibid.
[62] European Union. "Regulation (EU) 2024/1183 of the European Parliament and of the Council of 11 April 2024 on digital identity (eIDAS 2.0)". 2024. Ibid.
[63] European Union. "Regulation (EU) 2016/679 of the European Parliament and of the Council of 27 April 2016 on the protection of natural persons with regard to the processing of personal data and on the free movement of such data (General Data Protection Regulation – GDPR)". 2016. Ibid.
[64] United Nations. Global Compact for Safe, Orderly and Regular Migration. 2018. Ibid.
[65] Council of Europe. Recommendation CM/Rec(2021)8 of the Committee of Ministers to member States on the impacts of algorithmic systems on human rights. 2021. Ibid.
[66] Organisation for Economic Co-operation and Development (OECD). Government at a glance 2025: Full report. 2025. Ibid.

stability, as well as minimizing the error of expert agreement ($\sigma \leq 0.12$). The sample included representatives of state bodies, scientific institutions, and the IT sector, who have at least ten years of experience in the fields of digital governance, migration law, information security and data management.

In conceptual terms, LR captures the formal legal design and coherence of the regulatory framework (i.e., whether rules, mandates, and safeguards exist and are aligned with international/EU standards), whereas HCR captures the practical availability and effectiveness of human-rights safeguards in operation (i.e., accessibility of remedies, appeal channels, procedural protection, and oversight in real decision pathways). The two dimensions are related but intentionally separated to distinguish regulatory architecture from functional rights protection in practice.

The selection criteria were professional competence, professional publications, participation in the development of regulatory legal acts or the practical implementation of digital solutions in public administration. The survey was conducted as part of the second stage of the study in three stages. The first stage was an anonymous online survey using the Delphi method, in the Google Forms software environment with further processing of the results in Microsoft Excel 2025 to check the consistency of expert assessments, which included 12 questions: eight closed (with a five-point Likert scale) and four open for reasoning assessments. The respondents determined the weight of the four components of the index (DP, DET, LR, HCR), the acceptable level of compromise between efficiency and legal sustainability, and also assessed the risks of algorithmic bias and restrictions on the rights of migrants. At the second stage, the results were summarized and checked during focus group discussions (five experts from each country), where the final agreement of the weight coefficients was carried out using the pairwise comparison method (AHP). The final stage involved verification of the results through statistical analysis of consistency (Kendall W coefficient), which ensured the stability of the expert model. After three rounds of agreement, a weight system was formed that reflects the compromise between technological efficiency, legal legitimacy, and humanitarian orientation of digital systems: DP–0.35; DET–0.25; LR–0.25; HCR–0.15.

The questionnaire and assessment methodology are developed based on the principles of Regulation (EU) 2024/1183 (eIDAS 2.0)[67], Regulation (EU) 2016/679 (GDPR)[68], Recommendation CM/Rec(2021)8 Council of Europe[69] and the analytical guidelines of OECD Government at a Glance 2025[70], which define key criteria for transparency, legality, and protection of rights in digital governance. Unlike classic digital maturity indicators (DESI, EGDI), MDII measures not only technical efficiency and regulatory compliance, but also the level of ethical and legal balance, which allows assessing the extent to which digital migration control systems maintain a humanitarian focus and adhere to international human rights standards even in crisis conditions.

4.3. Methods of analysis

[67] European Union. "Regulation (EU) 2024/1183 of the European Parliament and of the Council of 11 April 2024 on digital identity (eIDAS 2.0)". 2024. Ibid.

[68] European Union. "Regulation (EU) 2016/679 of the European Parliament and of the Council of 27 April 2016 on the protection of natural persons with regard to the processing of personal data and on the free movement of such data (General Data Protection Regulation – GDPR)". 2016. Ibid.

[69] Council of Europe. Recommendation CM/Rec(2021)8 of the Committee of Ministers to member States on the impacts of algorithmic systems on human rights. 2021. Ibid.

[70] Organisation for Economic Co-operation and Development (OECD). Government at a glance 2025: Full report. 2025. Ibid.

Digital migration control mechanisms was assessed through a combination of quantitative, qualitative, legal, and logical methods, which ensured a comprehensive reproduction of the relationship between technological efficiency, legal stability and humanitarian orientation of the systems. At the quantitative level, a correlation and regression analyses were conducted using Pearson coefficients (to identify linear dependencies) and Spearman (to check the stability of results under conditions of non-normal distribution) between the components of the MDII, the E-Government Development Index (EGDI), and Rule of Law Index. The structural differences in the digital governance models of Poland, the UK, and Ukraine were compared through clustering using the k-means method to identify groups of countries with similar profiles of digital integration and regulatory maturity. At the qualitative level, the method of legal modelling of migration control processes according to the "condition - authority-restriction" scheme was applied to identify critical points of risk of human rights violations in automated decision-making. A content analysis of official regulations[71,72,73,74,75,76,77,78,79,80,81] was also conducted to determine the harmonization of national norms with European documents–GDPR[82], eIDAS 2.0[83], Recommendation CM/Rec(2021)8[84], and Government at a Glance 2025[85]. The reliability of the results was increased using the bootstrap simulation method (n = 500) was used to form confidence intervals for each MDII and check the stability of estimates between countries.

Given the limited number of observations (three countries assessed across three standardized scenarios), inferential statistics are interpreted cautiously. Correlation coefficients, PCA, and k-means clustering are used for exploratory pattern detection and visualization of multidimensional profiles rather than for population-level generalization or causal inference. Accordingly, the analysis avoids overclaiming statistical robustness and reports these procedures as descriptive and model-based tools supporting the comparative logic of the MDII framework.

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[71] Verkhovna Rada of Ukraine. Law of Ukraine "On the Unified State Demographic Register and Documents Confirming the Citizenship of Ukraine". 2024. Ibid.
[72] Verkhovna Rada of Ukraine. Law of Ukraine "On Electronic Public Services". 2023. Ibid.
[73] Sejm of the Republic of Poland. Ustawa z dnia 12 marca 2022 r. o pomocy obywatelom Ukrainy. 2024. Ibid.
[74] Ministerstwo Spraw Wewnętrznych i Administracji. Diia.pl – elektroniczny dokument dla uchodźców wojennych z Ukrainy, 2022. Ibid.
[75] United Kingdom. Data Protection and Digital Information Bill. 2024. Ibid.
[76] United Kingdom. Nationality and Borders Act 2022. 2022. Ibid.
[77] European Union. "Regulation (EU) 2024/1183 of the European Parliament and of the Council of 11 April 2024 on digital identity (eIDAS 2.0)". 2024. Ibid.
[78] European Union. "Regulation (EU) 2016/679 of the European Parliament and of the Council of 27 April 2016 on the protection of natural persons with regard to the processing of personal data and on the free movement of such data (General Data Protection Regulation – GDPR)". 2016. Ibid.
[79] United Nations. Global Compact for Safe, Orderly and Regular Migration. 2018. Ibid.
[80] Council of Europe. Recommendation CM/Rec(2021)8 of the Committee of Ministers to member States on the impacts of algorithmic systems on human rights. 2021. Ibid.
[81] Organisation for Economic Co-operation and Development (OECD). Government at a glance 2025: Full report. 2025. Ibid.
[82] European Union. "Regulation (EU) 2016/679 of the European Parliament and of the Council of 27 April 2016 on the protection of natural persons with regard to the processing of personal data and on the free movement of such data (General Data Protection Regulation – GDPR)". 2016. Ibid.
[83] European Union. "Regulation (EU) 2024/1183 of the European Parliament and of the Council of 11 April 2024 on digital identity (eIDAS 2.0)". 2024. Ibid.
[84] Council of Europe. Recommendation CM/Rec(2021)8 of the Committee of Ministers to member States on the impacts of algorithmic systems on human rights. 2021. Ibid.
[85] Organisation for Economic Co-operation and Development (OECD). Government at a glance 2025: Full report. 2025. Ibid.

4.4. Technical environment

The MDII calculations and statistical procedures were performed in Python 3.12 using the Pandas, NumPy, SciPy, Matplotlib, scikit-learn, and Seaborn libraries. The data sources were analysed based on the official databases EU DESI (2024), UN EGDI, World Justice Project Rule of Law Index (2024), and OECD open statistical reports (2025). Microsoft Power BI and Tableau Public were used to visualize the results, which provided an interactive presentation of the dynamics of digital readiness and legal compliance. Legal acts of Poland, Ukraine, and the UK were analysed using the official databases Sejm.gov.pl, Legislation.gov.uk, and zakon.rada.gov.ua. European norms were checked through EUR-Lex. Such a methodological architecture allowed combining technical, legal, and socio-ethical analysis, which provided a complete assessment of the balance between the effectiveness of digital tools and compliance with legal standards in the field of migration management.

5. Results

5.1. Comparative assessment of the digital integrity of migration control systems

A comparative analysis of three national models–Ukraine, Poland, and the UK–showed significant differences in the level of balance of technical efficiency, legal reliability, ethical transparency, and humanitarian orientation of digital migration control systems. The MDII was calculated using Formula (1), where the parameters DP, DET, LR, HCR are normalized in the range of 0–1. The obtained results shown in Table 2 reflect the average expert assessments and statistical data of the three countries.

Table 2. Normalized values of the DP, DET, LR, HCR and the integral MDII for Ukraine, Poland, and the UK.

Country	DP	DET	LR	HCR	MDII
Ukraine	0.82	0.63	0.68	0.55	0.70
Poland	0.79	0.75	0.80	0.76	0.77
UK	0.76	0.81	0.89	0.80	0.83

Source: calculated by the author based on[86,87,88,89] and expert assessment (Delphi–AHP, n = 30).

The results of Table 2 show that Ukraine has the highest Digital Performance (0.82), which indicates high technical efficiency and speed of implementation of electronic services in the field of migration control (in particular, digital services of the Diia platform). At the same time, the low HCR = 0.55 indicates the limitations of humanitarian mechanisms of appeal and legal protection in the context of automated decisions. Poland demonstrates the most balanced structure of the index: all parameters range within 0.75–0.80. This is explained by the harmonized combination of the legal framework (Ustawa z dnia 12 marca 2022 r. o pomocy obywatelom Ukrainy[90]) with the institutional integration of the PESEL UKR register

[86] Verkhovna Rada of Ukraine. Law of Ukraine "On Electronic Public Services". 2023. Ibid.
[87] Verkhovna Rada of Ukraine. Law of Ukraine "On the Unified State Demographic Register and Documents Confirming the Citizenship of Ukraine". 2024. Ibid.
[88] Ministerstwo Spraw Wewnętrznych i Administracji. Diia.pl – elektroniczny dokument dla uchodźców wojennych z Ukrainy, 2022. Ibid.
[89] Sejm of the Republic of Poland. Ustawa z dnia 12 marca 2022 r. o pomocy obywatelom Ukrainy. 2024. Ibid.
[90] Sejm of the Republic of Poland. Ustawa z dnia 12 marca 2022 r. o pomocy obywatelom Ukrainy. 2024. Ibid.

and the digital document Diia.pl[91], which ensure legal transparency and operational processing of migration data. The UK has the highest Legal Robustness score (0.89) because of the clearly defined Nationality and Borders Act[92] and Data Protection and Digital Information Bill[93]. However, the high level of legal rigidity is accompanied by a relatively sensitive DET indicator (0.81), which indicates the need to increase the transparency of the Home Office Digital Status algorithmic systems and external audit mechanisms. So, an analysis of the structure of the MDII shows that the Ukrainian model is focused on speed and technologicality, the Polish model—on institutional balance, and the British model—on legal stability and accountability in the field of digital migration management. Although the numerical differences between the country-level MDII scores may appear moderate (e.g., 0.83 vs. 0.77 vs. 0.70), their substantive meaning lies in consistent structural variation across all four components (DP, DET, LR, HCR) and in scenario-level stability. The index is designed to capture institutional balance rather than marginal quantitative separation. Accordingly, the interpretation of differences is based on multidimensional profile patterns and sensitivity across scenarios (S1–S3), not solely on the absolute magnitude of the composite score.

5.2. Scenario analysis of three typical migration management situations

The features of the functioning of digital migration control mechanisms were identified through a scenario analysis, covering three management situations typical of modern systems: S1—initial electronic identification of migrants, reflecting the initial stage of identity identification and data verification; S2—interdepartmental data exchange, which characterizes the level of technical compatibility and regulatory consistency between state bodies; S3—automated decision-making on status, residence permit or deportation, which is the most sensitive phase from the perspective of human rights and transparency of algorithms. Within each scenario, the MDII was calculated according to Formula (1), taking into account expert assessments and data from national registers. A visualization of the variations of the MDII index under three scenarios is shown in Figure 1.

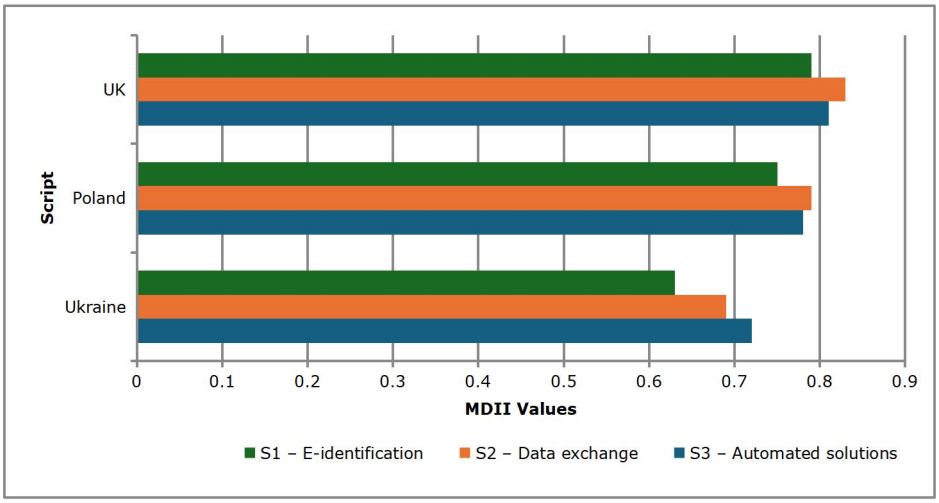

Figure 1. Variations of the MDII in migration management scenarios for Ukraine, Poland, and the UK. Source: constructed by the authors based on their own calculations (Python 3.12, Matplotlib, Seaborn).

[91] Ministerstwo Spraw Wewnętrznych i Administracji. Diia.pl – elektroniczny dokument dla uchodźców wojennych z Ukrainy, 2022. Ibid.
[92] United Kingdom. Nationality and Borders Act 2022. 2022. Ibid.
[93] United Kingdom. Data Protection and Digital Information Bill. 2024. Ibid.

The data in Figure 1 demonstrate that the British model of digital migration control is characterized by the highest stability of MDII indicators within the range of 0.79–0.83, which indicates the stability of legal and procedural mechanisms even in complex scenarios of automated decision-making. The Polish system maintains a balanced profile between technical efficiency, regulatory coherence and humanitarian orientation: the indicators fluctuate within the range of 0.75–0.79, which indicates consistent interaction between state registers and the presence of procedural control. The Ukrainian model, on the contrary, is characterized by the greatest variability–the MDII decreases from 0.72 in scenario S1 to 0.63 in scenario S3. This indicates the sensitivity of the system to limitations in algorithmic transparency and the need to strengthen legal guarantees in automated decision-making processes. So, the obtained results confirm that the high technological speed of the Ukrainian system needs to be supplemented by a stable regulatory and humanitarian component, while the British and Polish models demonstrate a better balance between efficiency, legality, and protection of migrants' rights.

5.3. Correlational validation of the MDII

The results of the correlation analysis confirmed the high consistency of the MDII with international indicators of digital maturity and legal stability of states. A comparison of three systems–Ukraine, Poland, and the UK–showed that the MDII demonstrates stable positive relationships with both the EGDI and the Rule of Law Index, which indicates its ability to adequately reflect the integration of technological efficiency and legal reliability in the field of migration management. The obtained data are presented in Table 3.

Table 3 shows that the highest level of correlation is observed between MDII and Rule of Law Index ($r = 0.83$; $p < 0.01$), which emphasizes the dominance of the legal component in the formation of digital integrity of systems. It should be noted that the high correlation of the MDII and Rule of Law Index is partially a product of theoretical proximity since Legal Robustness is one of the dimensions of the MDII. Thus, it should be interpreted as a validation of convergent validity rather than a validation of external measures that is fully independent. While the MDII expands institutional quality of law to measures of ethical transparency and human-centered safeguards, further validation against independent measures of governance would strengthen use of the MDII in the future.

The correlation with EGDI was $r = 0.77$ ($p < 0.05$), which indicates the relationship between the level of digital readiness of the state and the effectiveness of its digital mechanisms in the migration sphere. For Poland, as the only EU country in the sample, a moderate positive correlation of MDII with the Digital Economy and Society Index (DESI) was additionally determined–$r = 0.69$ ($p < 0.05$). The partial correlation between MDII and Rule of Law Index with DESI control showed a value of $rp = 0.68$, which indicates the independence of the relationship between digital integrity and legal stability from the level of overall digitalization. Figure 2 demonstrates a positive linear relationship between the MDII and the Rule of Law Index, confirming the construct validity of the index.

Figure 2 shows that there is a clear positive linear relationship between the MDII and the Rule of Law Index: as the legal stability of a state increases, the level of integrity of its digital systems in the field of migration control increases. The highest values of both indicators are recorded in the UK, which indicates the maturity of its regulatory infrastructure and the stability of digital identification procedures. Poland demonstrates a moderately high correlation between legal coherence and digital efficiency, while Ukraine, despite its high level of digitalization, has lower MDII indicators due to the lack of procedural certainty and the limited number of humanitarian control mechanisms in the digital environment. Because of the small-N problem, correlation coefficients and p-values should be treated with

caution. Statistical power is low in small-N studies, and coefficients may be sensitive to small changes. These caveats, then, treat the correlations as a descriptive feature of an experimental design rather than an inferential finding.

Table 3. Correlations of the MDII with international indicators of digital governance and the rule of law.

Pair of variables	r (Pearson)	r_s (Spearman)	95 % DI (bootstrap)	p-value	rp (partial)*
MDII–EGDI	0.77	0.73	[0.40; 0.92]	0.018	–
MDII–DESI (Poland)	0.69	0.66	[0.31; 0.87]	0.031	–
MDII–Rule of Law	0.83	0.80	[0.52; 0.94]	0.007	0.68 (contr. DESI)

Note: rp is the partial correlation of MDII with the Rule of Law Index, controlling for DESI. DESI is provided only for Poland as an EU member state; DESI is not available for Ukraine and the UK. Source: calculated by the authors in Python 3.12 (Pandas, SciPy, NumPy, Seaborn) based on[94,95,96,97,98,99,100,101,102,103,104], EGDI (2024), DESI (2024), Rule of Law Index (2024).

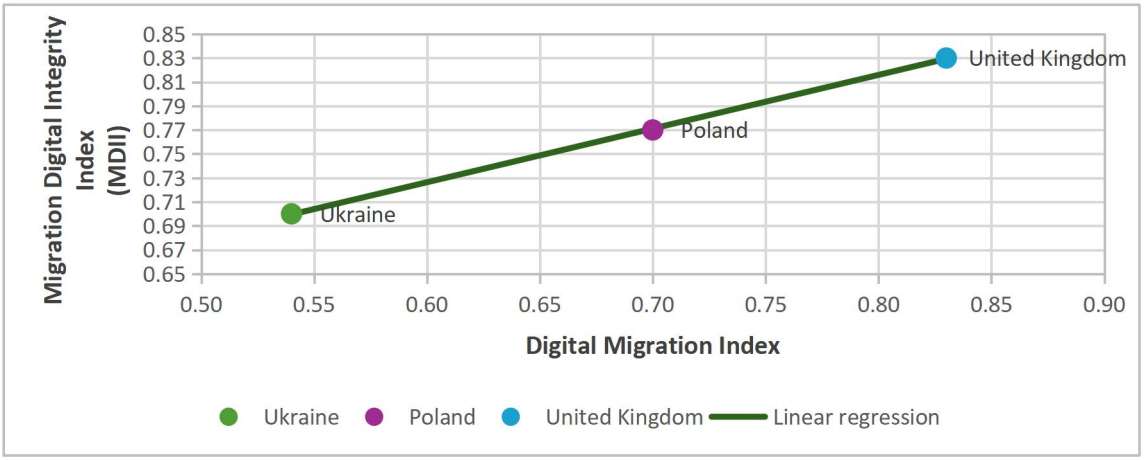

Figure 2. Correlation between the MDII and the Rule of Law Index. Source: calculated by the authors based on their own calculations (Python 3.12, Matplotlib, Seaborn).

[94] Verkhovna Rada of Ukraine. Law of Ukraine "On the Unified State Demographic Register and Documents Confirming the Citizenship of Ukraine". 2024. Ibid.
[95] Verkhovna Rada of Ukraine. Law of Ukraine "On Electronic Public Services". 2023. Ibid.
[96] Sejm of the Republic of Poland. Ustawa z dnia 12 marca 2022 r. o pomocy obywatelom Ukrainy. 2024. Ibid.
[97] Ministerstwo Spraw Wewnętrznych i Administracji. Diia.pl – elektroniczny dokument dla uchodźców wojennych z Ukrainy, 2022. Ibid.
[98] United Kingdom. Data Protection and Digital Information Bill. 2024. Ibid.
[99] United Kingdom. Nationality and Borders Act 2022. 2022. Ibid.
[100] European Union. "Regulation (EU) 2024/1183 of the European Parliament and of the Council of 11 April 2024 on digital identity (eIDAS 2.0)". 2024. Ibid.
[101] European Union. "Regulation (EU) 2016/679 of the European Parliament and of the Council of 27 April 2016 on the protection of natural persons with regard to the processing of personal data and on the free movement of such data (General Data Protection Regulation – GDPR)". 2016. Ibid.
[102] United Nations. Global Compact for Safe, Orderly and Regular Migration. 2018. Ibid.
[103] Council of Europe. Recommendation CM/Rec(2021)8 of the Committee of Ministers to member States on the impacts of algorithmic systems on human rights. 2021. Ibid.
[104] Organisation for Economic Co-operation and Development (OECD). Government at a glance 2025: Full report. 2025. Ibid.

5.4. Clustering of digital governance models

The results of the k-means clustering method (k = 3) carried out on the basis of four parameters of the digital integrity index–DP (technological performance), DET (data ethics and transparency), LR (legal reliability), and HCR (humanitarian resilience) distinguished three types of national models of digital migration governance. Preliminary dimensionality reduction using the PCA showed that the two principal components explain 88.2% of the total variance, which ensured the reliability of the two-dimensional classification model. The analysis of nine observations (three countries × three scenarios) showed that the UK forms a separate cluster with the highest indicators of legal maturity and ethical control (MDII = 0.82), which is consistent with the lawful-by-design model. Poland forms a second cluster with balanced values of all components (MDII = 0.78), which reflects the technological-humanitarian type of governance. Ukraine belongs to the third cluster, which is characterized by high technological activity under partial non-regulation (MDII = 0.68). Table 4 presents the profiles of digital migration governance clusters.

Table 4. Profiles of digital migration governance clusters (k-means method).

Cluster	Characteristics	DP	DET	LR	HCR	MDII (average)	Model type
1	High legal maturity, stability and control of algorithms	0.77	0.80	0.88	0.81	0.82	Great Britain – legal model
2	Technologically integrated, humanitarian-oriented model	0.80	0.76	0.80	0.77	0.78	Poland – technological-humanitarian model
3	High speed of digitalization, but partial legal unregulation	0.82	0.64	0.68	0.56	0.68	Ukraine – reformist model

Source: calculated by the authors based on their own data (Python 3.12, Pandas, scikit-learn, PCA + k-means).

Table 4 shows three clearly defined types of digital governance. The first cluster (Great Britain) is characterized by the highest indicators of legal reliability and ethical transparency (LR = 0.88; DET = 0.80), which indicates the maturity of regulatory control, stability of procedures, and the persistence of the principles of lawful-by-design in state digital services. The second cluster (Poland) demonstrates a balanced level of technological integration and humanitarian orientation (HCR = 0.77), which is due to the combination of interdepartmental compatibility of the PESEL UKR and Diia.pl registers with legal guarantees of data transparency. The third cluster (Ukraine) is distinguished by high DP indicators (0.82), but lower LR (0.68) and HCR (0.56) values, which indicates the reformist dynamics of development without full regulatory consolidation of the principles of ethical control and appeal procedures in digital systems. Spatial visualization of clusters is presented in Figure 3.

Figure 3 shows that the spatial distribution of clusters reflects a clear typology of digital migration governance models. Along the PC1 axis, representing technological efficiency and transparency, Poland, and the UK are located, with high indicators of digital maturity and structural data consistency. The UK dominates Along the PC2 axis reflecting legal reliability and humanitarian resilience, forming a stable "legal pole" of the cluster. Poland occupies an intermediate position–its observations gravitate towards the centre of the space, which indicates a balanced integration of technological and ethical parameters. Ukraine, on the other hand, is

concentrated in the lower part of the plane, forming a separate "reformist" cluster with high development potential but a lower level of regulatory stability. Thus, the PCA map confirms the three-class structure: the British model is a mature legal system, the Polish model is a technological and humanitarian balanced system, and the Ukrainian model is a dynamic and reformist one, which is in the transition phase to institutional stability.

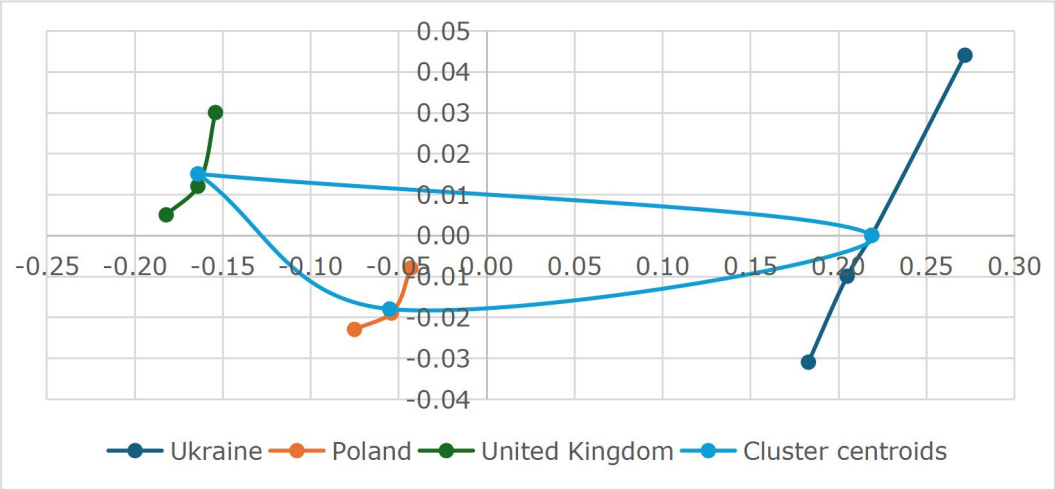

Figure 3. Spatial visualization of digital migration governance clusters (PCA + k-means method). Source: created by the authors in Python 3.12 (scikit-learn, Seaborn, Matplotlib).

5.5. Testing the reliability and sensitivity of the MDII

The reliability of the MDII was assessed through a bootstrap analysis of 1,000 resamplings (n = 1000, α = 0.05), which allowed to form 95% confidence intervals and check the stability of the obtained results. At the same time, a sensitivity test was performed for the variation of the weight coefficients of the index components (DP, DET, LR, HCR) within ±10%, which made it possible to identify the impact of changing the weights on the overall ranking of countries. The bootstrap procedure was applied to the scenario-extended component estimates underlying MDII aggregation (country × scenario profiles) in order to assess internal ranking stability. However, bootstrap resampling in a small-N comparative setting cannot substitute for broader empirical coverage and should be interpreted as a sensitivity illustration within the study design rather than as population-level uncertainty estimation. The results are presented in Table 5.

Table 5. Reliability and sensitivity of the MDII for Ukraine, Poland, and the UK.

Country	**Average MDII**	**95 % CI (bootstrap)**	**Variance**	**Rank change (±10%)**
Ukraine	0.70	[0.67; 0.73]	0.0019	0 ↔ −1
Poland	0.77	[0.75; 0.79]	0.0007	0
UK	0.83	[0.81; 0.84]	0.0004	0

Source: calculated by the author in Python 3.12 (NumPy, SciPy, Matplotlib).

Table 5 shows that all countries demonstrate a high level of stability of the MDII. The smallest variance and the narrowest confidence interval are recorded in the UK (σ^2 = 0.0004), which indicates a high stability of its digital migration governance model. Poland maintains moderate variability, but the ranking position remains unchanged even when the weight coefficients change. Ukraine demonstrates greater sensitivity—a shift in the weight parameters within ±10% leads to a possible decrease in the rank by one position, which indicates the dynamic nature of reforms and the gradual stabilization of the regulatory system.

So, the results of the bootstrap assessment confirmed the reliability of the MDII as a stable tool for quantitative analysis of digital integrity, while the sensitivity test revealed different degrees of structural stability of national models: the highest in the UK, balanced in Poland, while reformist and adaptive in Ukraine. Summarizing the results, it was found that the analysis based on the MDII and regulatory benchmarks [105, 106, 107, 108, 109, 110, 111, 112, 113, 114, 115] showed a different balance between technological efficiency, legal stability, and humanitarian orientation of national systems. Ukraine is characterized by high digital activity (DP = 0.82), but lower legal stability, which indicates an outstripping of technological development compared to regulatory consolidation. Poland demonstrates a balanced model, where legal reliability (LR ≈ 0.80) and humanitarian stability (HCR ≈ 0.76) ensure the reconciliation of efficiency and legality. The UK embodies a mature legal model lawful-by-design, built on clear regulations of the Nationality and Borders Act[116] and the Data Protection and Digital Information Bill[117]. Harmonizing the Ukrainian system with the provisions of eIDAS 2.0, GDPR, CM/Rec(2021)8, Global Compact for Migration, and OECD Government at a Glance 2025 is key to achieving a balance between digital efficiency, procedural legality, and human rights protection.

6. Discussion

The obtained results showed that the level of digital integrity of migration control systems is determined not only by technological efficiency, but primarily by the degree of legal integration, ethical responsibility, and institutional coherence. This is in line with the trend noted by Tjaden[118] and McAuliffe et al.[119], according to which the digitalization of migration policy is effective only when it combines technological innovations with legal guarantees. In this context, the MDII indicators confirm the conclusions of Witteborn[120] about the transformation of migration management into a process of "digitalization–digitization–datafication", where the

[105] Verkhovna Rada of Ukraine. Law of Ukraine "On the Unified State Demographic Register and Documents Confirming the Citizenship of Ukraine". 2024. Ibid.
[106] Verkhovna Rada of Ukraine. Law of Ukraine "On Electronic Public Services". 2023. Ibid.
[107] Sejm of the Republic of Poland. Ustawa z dnia 12 marca 2022 r. o pomocy obywatelom Ukrainy. 2024. Ibid.
[108] Ministerstwo Spraw Wewnętrznych i Administracji. Diia.pl – elektroniczny dokument dla uchodźców wojennych z Ukrainy, 2022. Ibid.
[109] United Kingdom. Data Protection and Digital Information Bill. 2024. Ibid.
[110] United Kingdom. Nationality and Borders Act 2022. 2022. Ibid.
[111] European Union. "Regulation (EU) 2024/1183 of the European Parliament and of the Council of 11 April 2024 on digital identity (eIDAS 2.0)". 2024. Ibid.
[112] European Union. "Regulation (EU) 2016/679 of the European Parliament and of the Council of 27 April 2016 on the protection of natural persons with regard to the processing of personal data and on the free movement of such data (General Data Protection Regulation – GDPR)". 2016. Ibid.
[113] United Nations. Global Compact for Safe, Orderly and Regular Migration. 2018. Ibid.
[114] Council of Europe. Recommendation CM/Rec(2021)8 of the Committee of Ministers to member States on the impacts of algorithmic systems on human rights. 2021. Ibid.
[115] Organisation for Economic Co-operation and Development (OECD). Government at a glance 2025: Full report. 2025. Ibid.
[116] United Kingdom. Nationality and Borders Act 2022. 2022. Ibid.
[117] United Kingdom. Data Protection and Digital Information Bill. 2024. Ibid.
[118] TJADEN, J. "Measuring migration 2.0: a review of digital data sources", Comparative Migration Studies, v. 9, n. 1, 2021, p. 59. https://doi.org/10.1186/s40878-021-00273-x
[119] McAULIFFE, M.; BLOWER, J.; BEDUSCHI, A. "Digitalization and artificial intelligence in migration and mobility: Transnational implications of the COVID-19 pandemic". 2021. Ibid.
[120] WITTEBORN, S. "Digitalization, digitization and datafication: the "three D" transformation of forced migration management", Communication, Culture and Critique, v. 15, n. 2, 2022, pp. 157-175. https://doi.org/10.1093/ccc/tcac007

quality of data and the degree of their legal protection become key criteria for trust. As Sabie et al.[121] noted, the effectiveness of digital systems is determined by the quality of interaction between a person, a state and an algorithm. The high MDII score in the UK (MDII = 0.83) is due to the regulatory clarity of the Nationality and Borders Act[122] and the Data Protection and Digital Information Bill[123], which provide a balance between security and the rule of law. The Polish model (MDII = 0.77) embodies a humanitarian-technological balance through the services Diia.pl and PESEL UKR, which is consistent with the position of Connolly et al.[124] on the need for clear mechanisms of legal control when processing personal data.

The correlational validation of MDII in the study confirmed that the rule of law is a key factor in digital integrity: the more stable the legal system of the state, the higher the level of transparency, ethics and predictability of algorithmic decisions. The positive relationship between MDII and the Rule of Law Index (r = 0.83) demonstrates that technological efficiency alone does not guarantee the appropriate level of digital trust—it is provided by the legal maturity of institutions. So, we can conclude that legislative integration is a crucial condition for achieving digital resilience.

Clustering, carried out using PCA and the k-means method, identified three types of national models of digital migration governance: British legal (lawful-by-design), Polish technological-humanitarian, and Ukrainian reformist. The obtained results are consistent with the conclusions of Sabie et al.[125], who argue that the effective use of digital technologies in the field of migration is possible only when algorithms are developed taking into account ethical principles and legal procedures. A similar opinion is expressed by Connolly et al.[126], emphasizing that the use of blockchain technologies to protect the rights of migrants is promising only if there are effective mechanisms for legal control and prevention of abuse in personal data processing. In this context, the results for the UK confirm the effectiveness of the lawful-by-design principle, while they indicate the need to develop appeal procedures and independent algorithmic audit for Ukraine.

The results of the study also demonstrate that Ukraine, despite significant progress in the digitalization of public services, needs deeper regulatory harmonization with European standards. The lack of clear procedures for algorithmic accountability and judicial review reduces the MDII indicators (0.70), especially in the aspects of humanitarian sustainability (HCR = 0.55). This is in line with the findings of Tjaden[127], who emphasizes that legal uncertainty in the field of digital migration policy can lead to discriminatory or opaque decisions. At the same time, the obtained data indicate that the reform dynamics of the Ukrainian model open up the potential for the introduction of new principles of ethical data management, in particular through the implementation of the requirements of Regulation (EU) 2024/1183 (eIDAS 2.0), Regulation (EU) 2016/679 (GDPR) and Recommendation CM/Rec(2021)8 of the Council of Europe. Yet at the same time, strong formal legality may not guard against risks of systematic informal denials of justice. Even the most formally elaborated purely digital status law models may create access conditions based on digital skills, the readiness of officials to respond

[121] SABIE, D.; EKMEKCIOGLU, C.; AHMED, S. I. "A decade of international migration research in HCI: Overview, challenges, ethics, impact, and future directions". 2022. Ibid.
[122] United Kingdom. Nationality and Borders Act 2022. 2022. Ibid.
[123] United Kingdom. Data Protection and Digital Information Bill. 2024. Ibid.
[124] CONNOLLY, D.; NAM, S.; GOODMAN, K. "Solving old problems or making new ones? Blockchain technology for the protection of refugees and migrants". 2023. Ibid.
[125] SABIE, D.; EKMEKCIOGLU, C.; AHMED, S. I. "A decade of international migration research in HCI: Overview, challenges, ethics, impact, and future directions". 2022. Ibid.
[126] CONNOLLY, D.; NAM, S.; GOODMAN, K. "Solving old problems or making new ones? blockchain technology for the protection of refugees and migrants". 2023. Ibid.
[127] TJADEN, J. "Measuring migration 2.0: a review of digital data sources". 2021. Ibid.

to queries, or even the contestability of algorithmic results. So, high marks on a formal legality test may still overlook problems of (substantive) access to justice and equality. This distinction between formal and informal legality and its procedural consequences remain an important source of tension in the context of digital migration law.

At the same time, the results of this study must be situated in the doctrinal context of migration law and international human rights law. As Karska[128] states, the management of migration in international law cannot be separated from the principles of state sovereignty, proportionality and the positive duty to guarantee effective protection of fundamental rights. The European concept of the aliens' protection, as established by Karska et al.[129], demonstrates that any administrative scheme affecting the migrants' legal position must be subject to guarantees regarding access to remedy, non-discrimination and procedural safeguards. Furthermore, Karska and Dąbrowski[130] demonstrate, in the instance of the Polish legal system, that eligibility for the status of protected person demands strict adherence to international and national standards even in situations of armed conflict and mass migration. These doctrinal considerations support the results of the present study: digital migration governance can only be legitimate and sustainable where algorithmic and data-based tools are restricted to a clearly delineated, human rights-compliant legal framework.

The quantification of complex normative values such as human rights protection, procedural fairness, and ethical transparency inevitably involves abstraction and simplification. While the MDII is designed as a structured multidimensional framework, it cannot fully capture contextual, socio-cultural, or experiential dimensions of migration governance. Therefore, the index should be understood as an analytical tool for comparative structuring rather than as a definitive measurement of justice or institutional morality. Its purpose is to facilitate structured evaluation, not to normalize or reduce deeply value-laden principles to purely numerical form.

So, the study confirms the main provisions of the current academic literature, but also offers a new systemic framework for assessing the integrity of digital mechanisms in migration governance. Comparative analysis proves that the highest efficiency is achieved by those systems in which technological solutions are integrated into a legally stable and ethically controlled environment. Such a pattern opens up prospects for further interdisciplinary research aimed at assessing the impact of algorithmic governance on human rights, the effectiveness of state institutions and the legitimacy of digital policies in the field of migration. Additional developments of the MDII may also be regional in the sense of non-EU jurisdictions and of jurisdictions that differ in their legal traditions, degrees of digitisation. Yet even developments of this kind are likely to lead to methodlogical difficulties of cross-regional and cross-jurisdictional kind; for example, regarding data availability,

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[128] KARSKI, K. "Migration". In: RAISZ, A. (ed.). International Law from a Central European Perspective. CEA Publishing, Budapest, 2022, pp. 219–238. https://doi.org/10.54171/2022.ar.ilfcec_10

[129] KARSKA, E.; MORAWSKA, E. H.; CZEPEK, J.; DĄBROWSKI, Ł. D.; ORĘZIAK, B.; GAŁKA, K. Human Rights in the European Paradigm of the Protection of Aliens. Cardinal Stefan Wyszyński University in Warsaw, Warsaw, 2023. Available at: https://wydzialy.uksw.edu.pl/wp-content/uploads/sites/10/2025/03/Human-Rights-in-the-European-Paradigm-of-the-Protection-of-Aliens_2.03.2025-ebook-1.pdf (accessed on 21 May 2025).

[130] KARSKA, E.; DĄBROWSKI, Ł. D. "Qualifying for international and national protection under the Polish legal order: Some remarks in the context of the war in Ukraine", Stosunki Międzynarodowe – International Relations, v. 59, 2023, pp. 7–21. https://doi.org/10.12688/stomiedintrelat.17794.1

heterogeneity of legal standards, the application of algorithmic governance, institutional capabilities.

7. Limitations

The results of this study need to be interpreted with certain methodological and conceptual limitations in mind. First, the analysis of the digital integrity of migration control systems was carried out for only three countries–Ukraine, Poland, and the UK, which limits the possibility of extrapolating the findings to other countries with different levels of legal integration, digital maturity or administrative structure. Second, the calculation of the MDII was based on four components–DP, DET, LR and HCR, while other potentially relevant factors (cyber resilience, public trust, institutional autonomy, economic efficiency) were not included in the model because of the limited available data. Third, the weights were determined on the basis of an expert survey with a relatively small sample (n = 30), which may affect the accuracy and reproducibility of the results. In addition, the scenario analysis covered only three typical governance situations (S1–S3), modelled on the basis of generalized assumptions, while the real behaviour of systems in crisis or politically sensitive conditions may differ significantly. The correlation validation of MDII was carried out on aggregated data of the EGDI, DESI and Rule of Law indices, without taking into account the time dynamics and internal sub-indicators. The study also did not cover the ethical, socio-cultural, and economic aspects of the implementation of digital control mechanisms, which may affect the balance between technological efficiency and legality. Further research should be aimed at expanding the sample of states, involving time series for dynamic analysis of MDII, integrating additional variables (citizen trust, level of cyber protection, appeal mechanisms), and testing the model on the basis of real migration cases. This will increase the validity of the MDII index and provide a deeper understanding of the sustainability of digital migration governance. As implemented for the time being, however, the MDII should be considered an exploratory comparison tool for assessing the tech-law equilibrium across a limited number of national regimes. While the index is in some ways suitable for expanded policy comparison, its application to disparate legal and regulatory systems requires empirical and methodological elaboration. Future research, however, may subject the MDII to testing in cross-regional samples to evaluate its validity as a universal comparison tool.

The small number of country cases diminishes statistical power and inferential statistics (e.g., p-values); thus, the quantitative findings are exploratory and illustrative but not conclusive. Here, correlation and clustering are used to gauge the model's reliability and illustrate country profiles, not to claim statistical associations among all units of analysis. Future studies should expand country numbers to be able to use sound inferential techniques for external validity. The limited number of country cases constrains statistical power and the stability of inferential measures. Quantitative outputs, including correlation coefficients and confidence intervals, should therefore be interpreted as exploratory within-sample assessments rather than externally generalizable statistical claims. Expanding the number of jurisdictions in future research would significantly strengthen external validity and inferential robustness.

8. Conclusions

The study confirmed that the effectiveness of digital technologies in the field of migration control is determined not only by the level of technical development, but primarily by the degree of legal coherence, ethical transparency, and humanitarian orientation of digital systems. A comparison of three national models–Ukraine,

Poland, and the UK–showed that the ratio between technological effectiveness and legality differs significantly. The UK demonstrated the highest integral indicator of digital integrity (MDII = 0.83), where the principle of lawful-by-design is implemented through a clear legal framework of the Nationality and Borders Act (2022) and the Data Protection and Digital Information Bill (2024). Poland (MDII = 0.77) is characterized by a humanitarian-balanced model that combines regulatory coherence and technical integration thanks to the PESEL UKR register and the digital document Diia.pl. Ukraine (MDII = 0.70) demonstrates high digital activity, but needs to strengthen legal and procedural mechanisms for appeal and control over algorithmic decisions. The correlation between MDII and Rule of Law Index (r = 0.83) confirmed that the rule of law is a key factor in ensuring the sustainability of digital governance. Clustering revealed three types of national models: legal (Great Britain), technological-humanitarian (Poland), and reformist (Ukraine). The obtained results prove the need to harmonize Ukrainian legislation with Regulation (EU) 2024/1183 (eIDAS 2.0), Regulation (EU) 2016/679 (GDPR), Recommendation CM/Rec(2021)8 of the Council of Europe, Global Compact for Migration (UN, 2018), and the OECD Government at a Glance 2025 framework. Strategic areas of improvement are the implementation of algorithmic audit mechanisms, strengthening appeal procedures, and independent control over digital decisions, as well as ensuring the interoperability of state registers while adhering to the principles of biometric data protection. The practical value of the study is the creation of a measurable analytical tool–the Digital Integrity Index (MDII), which can be used by government agencies, auditors, and international organizations to assess the legality, ethics, and effectiveness of state digital platforms in the field of migration. Its use allows for monitoring reforms, identifying weaknesses in algorithmic governance, and developing strategies for harmonization with European standards. The academic value of the study is the combination of legal, technological and humanitarian approaches in a single conceptual model of lawful-by-design, which integrates measurable indicators of digital efficiency with the parameters of the rule of law and human rights. The proposed methodology expands the toolkit of interdisciplinary research on digital governance and opens new directions for further research in the field of ethical use of artificial intelligence, algorithmic accountability and international standardization of digital migration systems. Prospects for further research include expanding the MDII framework to include AI accountability and data ethics indicators and testing the model on a sample of other EU countries to assess the sustainability of international digital migration management systems.

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