ICMPD
International Centre for Migration Policy Development

Working Paper

January 2025

Advances in Border Management: Digitalisation trends and emerging technologies

By Christina Khoury and Maegan Hendow

Executive Summary

Technological advancements are reshaping border management across the EU and beyond. Policymakers must respond quickly to evolving circumstances, including political and economic instability, climate change-induced natural disasters, and increased socio-political tensions. Governments increasingly deploy novel technologies and methods such as AI, biometric identification, and predictive analytics to enhance security and streamline border control processes. While these innovations may offer significant benefits, they also raise concerns about transparency, data protection, and the safeguarding of fundamental rights. In this context, this Working Paper tries to answer the following questions: How have technological developments transformed border management and what may the future look like? How is AI being leveraged for enhanced surveillance, predictive analytics, and risk assessment? What are the challenges that emerge from using these technologies, and how can policymakers address them while maintaining a balance between security imperatives and fundamental rights?

Drawing on expert discussions ICMPD has convened or participated in across international and regional fora, this paper examines the current state-of-the-art in border management technologies, assessing both their operational benefits and the risks they pose. It provides an overview of the latest advancements and trends in this regard, as related to its role in contemporary border management, with a specific focus on their application within the EU.

These key developments in border management technologies are analysed according to their functionality, including their capabilities and applications. In some cases, these areas overlap, both in terms of legal bases and the multi-functionality of specific tools, yet the analysis aims to highlight their specific roles in addressing operational needs and challenges. These are: border surveillance and pre-screening; risk analysis, nowcasting, early warning, and forecasting; database management and interoperability; and process facilitation.

Beyond these technological insights, this report also aims to discuss the implications for policymakers, and the strategies, opportunities, and challenges that they encounter in this domain. In considering border management strategies and reform with a view to new tools, it is important to factor in likely operational challenges as well, such as insufficient physical, technical and financial resources, or specific policy or regulatory needs.

Lastly, the report concludes with four major takeaways and recommendations. Firstly, the importance of capacity building and training to bridge the expertise gap in AI and to equip practitioners with the necessary skills to implement and operate new technologies in line with legal frameworks. Secondly, one of the strongest key takeaways is the urgent need for clear ethical and legal guidance, based on already existing frameworks, as modern border management requires a solid foundation on international ethical and legal principles. Thirdly, international collaboration and knowledge sharing play a critical role in ensuring responsible implementation of new technologies, and to achieving standardisation of migration data systems and interoperability aims. Lastly, in this area, technological integration and innovation should proceed with caution, making sure interventions are sustainable, updated, reliable and accurate through maintenance and rigorous testing. Deploying these technologies without addressing the institutional, legal, and operational dimensions of border management risks creating fragmented and ineffective systems. As technologies continue to develop, they require a focus on building systems that integrate effectiveness with fairness and transparency, ensuring that all stakeholders are considered in their deployment and use.

Contents

Acronyms and Abbreviations

ABC	Automated Border Control
ABIS	Automated Biometric Identification System database
ABPE	Admin-Based Population Estimate
ADAS	Airbus subsidiary Airbus DS Airborne Solutions
AI	Artificial intelligence
AIS	Automatic Identification System
API	Advance Passenger Information
ATOS	Airborne Tactical Observation and Surveillance
BCP	Border Crossing Points
CBM	Coordinated Border Management
CEAS	Common European Asylum System
CIR	The Common Identity Repository
CIRAM	The Common Integrated Risk Analysis Model
DRC	Danish Refugee Council
ECRIS-TCN	The European Criminal Records Information System on Third-Country Nationals
EES	Entry/Exit system
EMN	European Migration Network
EMPACT	The European Multidisciplinary Platform Against Criminal Threats
EMRTD	An electronic Machine-Readable Travel Document
EMT	EUMigraTool
EO/IR	Electro-optical / Infrared
EPS	Early Warning and Preparedness System
ETA	Electronic Travel Authority
ETIAS	The European Travel Information and Authorisation System
EU	European Union
EUAA	European Union Agency for Asylum
EURODAC	European Dactyloscopy Database
EUROPOL	European Police Office
EWS	Early warning systems
FRONTEX	European Border and Coast Guard Agency
GDPR	General Data Protection Regulation
IBM	Integrated Border Management
ICMPD	International Centre for Migration Policy Development
INTERPOL	International Criminal Police Organisation
IOM	International Organisation for Migration
IOT	Internet of Things
MAP	Migration anticipation and preparedness
MAS	Maritime Aerial Surveillance
MIDAS	The Migration Information and Data Analysis Systems
OECD	Organisation for Economic Co-operation and Development
PFT	The Norwegian Police Shared Services
PNR	Passenger Name Record
RAU	Frontex Risk Analysis Unit
RFI	Request for Information
RFID	Radio-frequency identification
SBMS	The secure border management system
SIS	Schengen Information System
SOP	Standard Operating Procedures
UAVS	Unmanned Aerial Vehicles

1. Introduction

Technological advancements are increasingly shaping border management policies and practices across the EU, its Member States and beyond. Governments are turning to new technologies including artificial intelligence (AI), biometric identification, and predictive analytics to strengthen border control and mitigate security risks.[1] While these technologies are presented as solutions to border management challenges, they also raise significant concerns and are the focus of criticism for lack of transparency, data protection, and potential risks to fundamental rights.[2] Against this backdrop, this report examines the current state-of-the-art in border management technologies, assessing both their operational benefits and the risks they pose. It provides an overview of the latest advancements and trends in technology, as related to its role in contemporary border management, with a specific focus on their application within the EU. Given the wide range of functionalities of these technologies, we first provide an overview of new developments in the deployment of new technologies or digitalisation trends according to main areas of application. In particular, we examine their use for conducting border control at a distance, either through surveillance technologies or pre-screening functions; then we examine their use for assessing wider risks for border management actors, through forecasting and foresight. Following this, we examine the myriad recent developments in identity management, especially in terms of new databases and the role of interoperability in this regard. Then, we focus on where technology is used to facilitate processes at border crossing points.

Beyond these technological insights, this report also aims to discuss the implications for policymakers, shedding light on the opportunities and challenges posed by these advancements. What has been achieved so far and what will the future look like? How has digitalisation transformed border management? How is AI being leveraged for enhanced surveillance, or predictive analytics, and risk assessment? What are the challenges that emerge from using these technologies, and how can policymakers address them while maintaining a balance between security imperatives and fundamental rights?

These insights are drawn from desk research, as well as expert discussions and consultations. In particular, the paper also builds on knowledge shared during key conferences that took place in 2024, namely the IBM Regional Conference that took place in Amman, Jordan under the title 'Embracing Modernisation: Artificial Intelligence and Digitalisation in Border Management', the side event at the Vienna Migration Conference 'On the brink of a new era: Navigating the future of tech in migration' on 22 October, the EMN Luxembourg and Prague Process Joint Workshop on "Forecasting and New Technologies in Migration and Asylum Governance: State of Play and New Developments" on 5-6 November 2024, and the 7th International Border Management Conference, that took place in Tunis, Tunisia on 27-28 November 2024.

[1] European Parliament, 'Artificial Intelligence at EU Borders - Overview of Applications and Key Issues', 2021, https://www.europarl.europa.eu/RegData/etudes/IDAN/2021/690706/EPRS_IDA(2021)690706_EN.pdf.

[2] OSCE, 'Border Management and Human Rights', 2021, https://www.osce.org/files/f/documents/f/a/499777.pdf.

2. Context and policy priorities for the EU

Managing borders is a challenging task and has intensified in recent years in the context of amplified passenger flows, hybrid and emerging threats (e.g. COVID-19) and increased attention to irregular migration flows across borders. To address emerging developments and to prepare for difficult decisions, policymakers and officials must respond quickly to evolving circumstances.[3] Globally, political and economic instability, as well as climate change-induced natural disasters, are leading to levels of displacement not seen since the end of World War II. The unforeseen migratory flows of the so called 2015/2016 refugee crisis in Europe prioritised developments related to migration forecasting.[4] Since, migration and border management have become more central policy issues, amplified by irregular migration through the Mediterranean and the challenges posed by Schengen area dynamics.[5] This period also marked a shift in terms of linking migration to security issues post-2015 in Europe and post-2001 in the US, where migration was framed as a problem, a threat or a global challenge, rather than as a source of social and technological innovation. This has, in return, resulted in heightened socio-political tensions and social exclusion.[6]

At the same time, hybrid and emerging threats have become significant for border management policy and practice: lessons from the instrumentalisation of migration crisis in the EU in 2021, as well as various health emergencies (Ebola outbreak of 2014, COVID-19 pandemic) have intensified the focus on hybrid- and health-related risks in border management. These crises prompted the implementation of a stringent border controls and efforts to improve forecasting efforts. They have also renewed the case for border management systems to properly identify and defuse threats to public health prior to points of entry.[7]

Amid these changes, the European Pact on Migration and Asylum, together with the amendments to the Schengen Borders Code and EURODAC, upcoming Entry-Exit System and ETIAS, interoperability rules, new EU Screening Regulation and the Common Identity Repository (CIR), plan to enhance the response of border control and migration management authorities to the instrumentalisation of migrant flows, secondary movements, and health crisis.[8] Part and parcel of these new policy developments are the collection of new forms of data for advanced risk assessments (e.g biometric and alphanumeric data collection and registration, security checks, health checks, vulnerability assessments, etc).

Against this background, promoting cross-border and regional cooperation is considered a key priority, through new and promising forms of migration partnerships. In this context, the demand

[3] PwC, 'The Future of Border Management: Maintaining Security; Facilitating Property', 2015.
[4] Marcello Carammia, Stefano Maria Iacus, and Teddy Wilkin, 'Forecasting Asylum-Related Migration Flows with Machine Learning and Data at Scale', *Scientific Reports* 12, no. 1 (1 December 2022), https://doi.org/10.1038/s41598-022-05241-8.
[5] Maegan Hendow, 'CROSSING EU BORDERS IN THE NEXT 15 YEARS', 2018.
[6] Miguel A. Centeno et al., 'The Emergence of Global Systemic Risk', *Annual Review of Sociology* 41, no. 1 (14 August 2015): 65–85, https://doi.org/10.1146/annurev-soc-073014-112317.
[7] IOM, 'Border Management and Health during Times of Pandemic: Lessons from COVID-19', 2022.
[8] Frontex, 'Strategic Risk Analysis 2024 Report', 2024.

for rapid and effective response in border management is consistently growing. For Europe, employing a whole-of-route approach has become central to its partnerships with countries in its neighbourhood and further afield. This includes in the context of border management: the European Council guidelines emphasise strengthening border management capacities of partner countries as part of the external dimension of EU migration policies. This approach is taken as a whole-of-route approach, in close cooperation with countries of origin and transit, and carried out in synergy with EU Agencies such as the European Border and Coast Guard Agency (Frontex), the EU Asylum Agency (EUAA) and Europol. This cooperation aims to support partner countries manage migratory flows effectively.[9] Some of these cooperations include *Türkiye*, supporting its border management capacities, as well as with the *Eastern Neighbourhood*, within the Eastern Partnership framework, for example supporting the implementation of visa facilitation (with Armenia, Azerbaijan and Belarus), and readmission agreements.[10]

Other cooperation includes countries in the *Western Balkans*, considering it a strategic priority for the EU in regards to accession process and on migratory routes to the EU. This includes a wide range of cooperation agreements covering border and migration management, as well as joint operations conducted across the region. Border and migration management along the Western Balkan route is considered a joint effort, and the 70% decrease of irregular border crossings in 2024 is attributed to strong cooperation with partners in the region.[11] One notable example is the joint operation that was launched in 2019 between Frontex and Albania, marking the agency's first fully-fledged mission outside the EU, where it deployed officers, patrol cars, and a thermos-vision van to support Albania in border control and tackling cross-border crime.[12] Finally, support is also provided to countries within the wider context of EU accession processes, relevant for Ukraine, Moldova, Bosnia and Herzegovina, as well as Georgia with candidate status as part of its 2023 Enlargement Package.[13]

When it comes to this dynamic landscape, operations, strategic planning, and innovation initiatives aim to leverage advanced tools developed from emerging technologies to secure and efficiently operate at the international border. [14] In recent years, technology has secured an

[9] European Commission, 'EU Support to Partner Countries on Migration and Forced Displacement', 2024, https://neighbourhood-enlargement.ec.europa.eu/european-neighbourhood-policy/eu-support-partner-countries-migration-and-forced-displacement_en.
[10] European Commission, 'Eastern Partnership', 2021, https://home-affairs.ec.europa.eu/policies/international-affairs/collaboration-countries/eastern-partnership_en.
[11] European Commission, 'EU Support to Partner Countries on Migration and Forced Displacement'.
[12] Frontex, 'Frontex Launches First Operation in Western Balkans', 2019, https://www.frontex.europa.eu/media-centre/news/news-release/frontex-launches-first-operation-in-western-balkans-znTNWM#:~:text=Today%2C%20Frontex%2C%20the%20European%20Border,and%20tackling%20cross%2Dborder%20crime.
[13] European Commission, 'Commission Adopts 2023 Enlargement Package, Recommends to Open Negotiations with Ukraine and Moldova, to Grant Candidate Status to Georgia and to Open Accession Negotiations with BiH, Once the Necessary Degree of Compliance Is Achieved', 2023, https://ec.europa.eu/commission/presscorner/detail/en/ip_23_5633.
[14] Frontex, 'EMERGING TECHNOLOGIES ARE RESHAPING THE BORDER LANDSCAPE', 2023.

important position in debates and policy development in the field of migration. Critics of border surveillance and biometric technologies argue that EU policymakers put forward 'techno-solutionist' arguments, framing migration as a threat that can only be managed though the procurement and deployment of these new technologies, the granting and expenditure of millions of euros on advanced border control (border checks and border surveillance), and biometric identification technologies. Additionally, concerns around secrecy and lack of transparency in the deployment of these technologies further challenge the perception of their effectiveness, raising question about their actual impact beyond political narratives.[15] Among various developments, artificial intelligence (AI) has emerged as a transformative tool, with the potential to reshape how governments manage border security, mobility, and related processes. In addition, the use of AI has been facilitated by the increased digitisation of mobility and migration processes by a growing number of governments and authorities worldwide.[16] Digital transformation has expanded to encompass nearly all aspects of migration management. This includes data collection, transferred in a secure environment, and data analysis in the decision-making process. It also applies to visa application and processing systems, border management systems, identity management using biometrics, pre-arrival screening, compliance fraud prevention, and refugee resettlement.[17]

In line with these developments, in the area of border management, there have also been increased investments in automation, digitalisation and other processes to support the interoperability of databases and facilitate analysis of big data, due to the extensive data collected in migration and travel systems.[18] As these technologies continue to evolve, they are not only transforming migration systems but also reshaping long-standing trends and operational paradigms in border management.[19] In this context, border management systems must adapt to new paradigms and realities that demand innovative tools and strategies. Indeed, migration and border management policies increasingly turn to new technologies to support their objectives, yet tend to be "tech-neutral", to allow for innovation within longer-term planning. The state-of-the-art technology key component of the new EU Technical and Operational Integrated Border Management (IBM) Strategy for external borders, for example, highlights the potential role of advanced border control systems, AI-powered risk analysis, biometric identity verification, interoperable data platforms, and automated border control solutions. Furthermore, the 2025 UK Border Strategy, for example, sets out their vision to have a border that embraces innovation,

[15] Karamanidou Lena, 'Surveillance Technologies at European Borders - Assessment on Evros', 2024.
[16] Martina Tazzioli, 'Counter-Mapping the Techno-Hype in Migration Research', *Mobilities* 18, no. 6 (2 November 2023): 920–35, https://doi.org/10.1080/17450101.2023.2165447.
[17] VFS Global, 'Enhancing Border Management Systems Using Artificial Intelligence', 2023, https://www.vfsglobal.com/en/individuals/insights/enhancing-border-management-systems-using-artificial-intelligence.html.
[18] PICUM and ecre, 'Beyond Walls and Fences: EU Funding Used for a Complex and Digitalised Border Surveillance System', 2024; Alberto Tagliapietra, 'Technologies and Borders The EU Is Digitalizing Migration Externalization', 2023.
[19] Ana Beduschi, 'International Migration Management in the Age of Artificial Intelligence', *Migration Studies* 9, no. 3 (15 December 2021): 576–96, https://doi.org/10.1093/migration/mnaa003.

simplifies processes for traders and travellers, and improves security and biosecurity of the UK, including the implementation of an Electronic Travel Authorisation.[20]

Looking at the current border security landscape, it seems increasingly diverse, utilising traditional methods like physical monitoring as well as advanced techniques such as electronic surveillance, pre-arrival information systems, biometric screening, biometric matching data and data-driven technologies.[21] In the area of smuggling, where migrant smugglers are notoriously flexible in adjusting modus operandi to new policy or operational changes, technological advancements are likely to play an important role.[22] Smugglers are likely to adapt their methods in order to improve efficiency and elude detection, for example through encrypted communication channels, block-chain-based transactions and sophisticated surveillance systems, through which they are able to quickly adapt their offer of services accordingly.[23] Addressing this is of high priority for the EU: the European Multidisciplinary Platform Against Criminal Threats (EMPACT) has identified combatting the facilitation of irregular migration as one of their top priorities for the period 2022 – 2025. [24] Europol's Migrant Smuggling Centre has also highlighted the potential links between organised criminal groups involved in smuggling and those involved in other crimes. For this reason, the EU's new European Criminal Records Information System - Third Country Nationals (ECRIS-TCN) database is considered a tool for cross-border law enforcement and border management, under the wider interoperability framework.[25]

However, as new technologies collect an increasing amount of data and AI-driven systems become more prevalent, concerns over transparency, data privacy, and potential fundamental rights violations have grown, underscoring the need for critical oversight in their implementation. Thus, it is of importance to also focus on how these technologies affect migrants and travellers.[26] In addition, there is concern that states may deploy advanced AI surveillance tools to monitor and track individuals to accomplish a range of policy objectives, some lawful, and others that violate human rights and fall into 'murky middle ground'.[27] This includes also social media

[20] Home Office Government, '2025 UK Border Strategy', 2020.
[21] Marco Lopez, 'The Future of Border Security: Harnessing AI and Emerging Technologies', 2024.
[22] Frontex, 'Strategic Risk Analysis 2024 Report'.
[23] European Union, 'ACTION DOCUMENT FOR THE EUROPEAN UNION EMERGENCY TRUST FUND FOR STABILITY AND ADDRESSING THE ROOT CAUSES OF IRREGULAR MIGRATION AND DISPLACED PERSONS IN AFRICA', 2020, https://neighbourhood-enlargement.ec.europa.eu/system/files/2021-02/modification_border_management_programme_for_the_maghreb_region.pdf.
[24] European Council, 'Fighting Migrant Smuggling and Human Trafficking', 2024, https://www.consilium.europa.eu/en/policies/eu-migration-policy/migrant-smuggling-human-trafficking/.
[25] Europol, 'Tackling Threats, Addressing Challenges - Europol's Response to Migrant Smuggling and Trafficking in Human Beings in 2023 and Onwards' (Luxembourg, 2024).
[26] #ProtectNotSurveil, 'EU #Protect Not Surveil', 2024, https://protectnotsurveil.eu/.
[27] Steven Feldstein, 'The Global Expansion of AI Surveillance', 2019.

monitoring.[28] The persistent lack of transparency in implementing such technologies,[29] including AI, have been criticised for their impacts on fundamental rights, such as non-discrimination and right to effective remedy.[30]

3. Technology in modern border management: State of the art and ways forward

Over the past quarter century, globalisation and digital innovation have revolutionised border management. Countries began to integrate real-time data collection and data analysis with centralised systems that enable more accurate control over border control activities. For example, radio-frequency identification (RFID) technology facilitated secure cross-border mobility of bona fide travellers, biometric passports verification using advanced Biometric Matching System (BMS), and electronic visa systems similarly facilitated travellers' cross-border mobility.[31] As border control systems have evolved, leveraging these technologies has brought both opportunities and challenges. The processes of risk analysis, profiling, intelligence led policing, intelligence data exchange, and queries in entry and exit systems have become significantly more straightforward.[32] Proponents argue that this has improved efficiency by enabling faster traveller screening and facilitating better identification of potential threats through enhanced data integration and analysis. Yet, critics highlight the potential for such systems to feed into discriminatory practices, as well as potential violations of fundamental rights like data protection and privacy.

This chapter reflects on developments in border management, across key areas where technology has played a significant role. It provides an overview of the current state of the art, as well as indications of future developments. To structure this discussion, the chapter is organised into sub-sections that examine how technology contributes to broader processes related to border management. Rather than solely focusing on individual technologies (which are used in myriad ways), we explore their role within key operational areas. This approach ensures a holistic understanding of how digital tools shape border control strategies, the synergies between different technological solutions, and the challenges they present.

3.1 Border surveillance and pre-screening

This section reflects on where technology is used to support border control processes conducted from a distance, either through border surveillance at blue and green borders, or through pre-screening. Although under the Schengen Borders Code for the EU this is only one part of border

[28] Privacy International, '#PrivacyWins: EU Border Guards Cancel Plans to Spy on Social Media (for Now)', 2019, https://privacyinternational.org/advocacy/3289/privacywins-eu-border-guards-cancel-plans-spy-social-media-now.
[29] Clara Isabel Velasco Rico and Migle Laukyte, 'ETIAS System and New Proposals to Advance the Use of AI in Public Services', *Computer Law & Security Review* 54 (September 2024): 106015, https://doi.org/10.1016/j.clsr.2024.106015.
[30] Hendow, 'CROSSING EU BORDERS IN THE NEXT 15 YEARS'.
[31] David Tashji, 'Smart Borders: How Technology Is Tracking You ', PWK International, 2024.
[32] Frontex, 'Strategic Risk Analysis 2024 Report'.

control, we discuss separately technology used directly at border crossing points in interactions with migrants and travellers (as process facilitation, Section 3.3), as well as new forms of analysis such as forecasting and foresight (Section 3.2).

In analysing new developments in this area, such systems employ state-of-the-art technology to monitor more remote areas of the border, to support border control along green and blue borders in particular, but also to reinforce border checks operations within the border crossing points (BCPs). Security concerns stemming from the terror attacks in Spain and France in the early 2000s led to a push for the use of innovative technologies at the border. In the years since, technologies such as e-gates, automated security checks, software for risk assessment of travellers, and biometric identifiers have become a part of crossing a border and of EU border monitoring.[33] However, challenges such as technical malfunctions, high operational costs, and concerns about data privacy and ethical implications have also emerged, highlighting the need for robust oversight and continual improvements. In recent years, however, the collection of biometric data by advanced technology from people on the move has received sharp criticism from civil society organisations, who denounce the fundamental rights implications of such intrusive technology,[34] particularly the risks of racial profiling, excessive data retention, and lack of legal safeguards for affected individuals.[35]

Whereas previous iterations of these technologies at the border implied video surveillance, heat sensors and alerts, the latest trends involve the digitisation and "smartification" of the border. Here, states use information technology to create a smart border: a diffuse border that cannot be geographically localised, but rather relies on numerous physical and virtual locations of control and surveillance, which are connected through a digital network.[36] In this approach, border control begins already at the point of departure, through pre-arrival risk analysis, using data processing technologies and AI to assess risks associated with individuals and goods before they reach the border, enabling authorities to make informed decisions in advance (e.g API, PNR data), and continues through the entire mobility process. This reflects an increasing shift towards border control at a distance, where surveillance technologies extend control beyond traditional entry points and allow authorities to track movements, identify risks, and intervene in real time. However, these methods have also raised some ethical concerns regarding the presumption of risk based on algorithmic profiling, leading to discrimination, but also causing significant harm in some instances, for example asylum seekers being incorrectly returned to their country of origin or an unsafe country, with the possibility of facing persecution (refoulement).[37] To avoid this and subsequent potential violations of fundamental rights, the EU's Fundamental Rights Agency has

[33] Alberto Tagliapietra, 'Technologies and Borders - The EU Is Digitalizing Migration Externalization', 2023.
[34] Noah Hatchwell and Pauline F, 'Surveillance Technologies at European Borders - An Assessment of Serbia', 2024.
[35] OSCE, 'Border Management and Human Rights'.
[36] Kristina Korte, "'So, If You Ask Whether Fences Work: They Work"—the Role of Border Fortifications for Migration Control and Access to Asylum. Comparing Hungary and the USA', *Comparative Migration Studies* 11, no. 1 (2 October 2023): 29, https://doi.org/10.1186/s40878-023-00352-1.
[37] Madeleine Forster, 'Refugee Protection in the Artificial Intelligence Era - A Test Case for Rights', 2022.

provided concrete recommendations for policymakers, information technology experts and officers.[38]

With regard to how new technologies are used to support border surveillance, there are a wide range of activities taking place at the EU and Member State level. At the EU level, Frontex plays a critical role not just in monitoring developments across the EU based on operational data collected across the EU Member States, but also in terms of their own surveillance assets. Operating 24/7, they maintain a comprehensive view of Europe's borders by monitoring and analysing data across continent. This allows them to have a Europe-wide view of border control and migration management. They use their own surveillance assets, and also receive, integrate, analyse, and disseminate intelligence from variety of sources, including national border guard authorities. For example, Frontex's Advanced Border Surveillance (EUROSUR 2.0) provides situational awareness for border guards, implements maritime and land border surveillance through AI and satellite monitoring, and is used to detect irregular crossings, migrant smuggling, and human trafficking activities. Moreover, Frontex's Maritime Aerial Surveillance (MAS) has become an important part of their operations, and a permanent service offered to national authorities.[39] Their multiple planes and drones patrol selected areas beyond the EU external borders as part of MAS, and this surveillance is to also establish an early warning mechanism.[40] The majority of Frontex operations are carried out over the central Mediterranean, with aircraft and drones stationed in Italy, Malta and Greece, as well as over the British Channel for Belgium and France. Additionally, Frontex is also deploying manned aircraft in Romania and Spain as part of its operations. Their reports are generated using images from satellites launched by the EU as part of the Copernicus programme.[41]

The EU is also active in supporting the implementation of state-of-the art border surveillance capacities in third countries. In a 2022 announcement of the Western Balkan Action Plan aiming to reduce irregular migration flows, address migrant smuggling and improve returns, the EU emphasised capacity building for border surveillance, hand-in-hand with support to implement border control and registration systems. Millions of euros were made available for border management, judicial and police cooperation, strengthening capacities and key infrastructure and equipment, to be implemented in Bosnia, Montenegro, Kosovo, and Serbia.[42] However, outsourcing border surveillance to non-EU countries raises significant ethical concerns, as these states may lack the legal and institutional safeguards necessary to prevent human rights violations. Some critiques have argued that this outsourcing and such externalisation strategies

[38] FRA, 'Bias in Algorithms – Artificial Intelligence and Discrimination', 2022.
[39] Frontex, 'Monitoring and Risk Analysis', 2024.
[40] Frontex, 'Operations', 2024, https://www.frontex.europa.eu/what-we-do/operations/search-and-rescue/.
[41] Matthias Monroy, 'Frontex Expands Aerial Surveillance: More Deployments of Planes, Drones and Surveillance Satellites', 2024.
[42] European Commission, 'Migration Routes: Commission Proposes Action Plan for Cooperation with Western Balkans to Address Common Challenges', 2022, https://ec.europa.eu/commission/presscorner/detail/es/ip_22_7447.

are mainly focused on operational efficiency rather than the humanitarian considerations (such as the treatment of migrants).[43]

Where surveillance is concerned, the private sector plays an important role in developing new technological tools, including drones. Unmanned Aerial Vehicles (UAVs), or drones, are considered a versatile and efficient solution for monitoring and protecting borders. Their operational advantage is providing a bird's eye view of long stretches of land, including remote regions, and challenging terrains. These drones are usually equipped with high-resolution cameras and advanced sensors, and can capture real-time imagery, detect movements, and identify potential threats along the border. From a border management perspective, similar to early warning systems, drones allow for advanced and efficient deployment capabilities, in comparison to the traditional methods (ground patrols, fixed surveillance systems), especially as they can be repositioned to areas of interest as needed.[44] Many of the technological tools deployed in this area are adapted from military use.[45] Where UAVs are engaged, critics have also raised the issue of privacy and security, in continuous monitoring, and the collection of biometric data without consent, as well as security vulnerabilities.[46]

The Airbus subsidiary Airbus DS Airborne (ADAS), for example, is contracted to provide a medium-altitude, long-endurance drone Maritime Heron. The Maritime Heron can stay in the air for over 20 hours, collecting surveillance data over the Mediterranean by using electro-optical and thermal infrared sensors. Additionally, it is equipped with a high-performance maritime patrol radar and an automatic identification system. Upon collection of data, it is sent to Frontex's operational command centre in Warsaw and the control centres of the relevant European host countries, enabling them to coordinate rescue operations in real-time.[47]

In terms of operational response, the Frontex Situation Centre is established based on three pillars: their Frontex Surveillance Sector, their Monitoring HUB and their Crisis Cell. In Frontex's surveillance sector, they use real-time aerial and maritime surveillance, as well as state-of-the-art technology and international expertise. The aerial surveillance, for example, is activated to provide national and European authorities with "eyes in the skies", while for the maritime surveillance, they monitor vessels of interest sailing across the world to provide timely and accurate information to Member State authorities. In conducting this surveillance, they deploy drones (the Sparow flight, the Eagle and the Heron), which operate in all weather conditions, as

[43] statewatch, 'Outsourcing Borders Monitoring EU Externalisation Policy', 2024.
[44] M Durgut, 'Enhancing Border Security and Surveillance with UAV Technology: A Game-Changer in Homeland Defense', 2023.
[45] Inkwood Research, 'GLOBAL UNMANNED AERIAL VEHICLE MARKET FORECAST 2021-2028', 2021.
[46] Inijah Quadri, 'The Impact of Autonomous Drones on Privacy and Security', Social Justice Policy Brief #171, 2025.
[47] Aeromag, 'Airbus and IAI Extend Maritime Surveillance Services for Frontex', 2024, https://www.aeromagasia.com/2024/12/18/airbus-and-iai-extend-maritime-surveillance-services-for-frontex/.

well as radar, the AIS (Automatic Identification System)[48] and the EO/IR (Electro-optical / Infrared)[49] systems.[50]

New developments in this area can be identified outside the EU and in specific areas of technological development. South Africa's Leonardo's ATOS (Airborne Tactical Observation and Surveillance) system is a platform that has been lauded for its potential to revolutionise how both law enforcement and the military operate. It is an integrated, multi-sensor, and multi-platform system that provides high-end surveillance, monitoring and command and control capabilities for security operations. This system is modular and adaptable, meaning that it can be leveraged on a variety of platforms, from manned aircraft and UAVs to land-based command posts, as it can cover a wide range of areas.[51]

In the field of border surveillance, AI is considered a pioneering technology, given that it generates real-time alerts and can work without human intervention, such as using AI-drones for patrolling areas. It can also identify patterns in data, as well as integrate with the Internet of Things (IoT) devices, such as sensors and smart cameras, to create a surveillance network.[52] While integrating AI and other new technologies have been lauded for their potential, they may also pose operational risks, especially arising from irresponsible development and use, such as opening up the possibility for criminal and cyberattacks against border infrastructure.[53] However, border agencies consider the possibilities to outweigh the risks, deploying them to improve the capabilities of national authorities, for example, AI-powered systems and tools for border checks, border surveillance, and intelligence and risk assessment, keeping in mind that border authorities need to maintain a delicate balance between leveraging AI's benefits and addressing its limitations.[54]

Yet, each technology comes with technical shortcomings. For surveillance technologies, some of the limitations include sensors susceptible to false positives, high operational costs,

[48] The AIS is a short-range coastal tracking system currently used on ships. It was developed to provide identification and positioning information to both vessels and shore stations. See https://connectivity.esa.int/satellite-%E2%80%93-automatic-identification-system-satais-overview

[49] Electro-optic infrared systems are a type of sensor technology that uses a combination of optics and electronics to detect, track, and identify objects or targets in the infrared spectrum. See https://www.ansys.com/blog/ansys-solution-overview-electro-optic

[50] Frontex Situation Centre, 'Harnessing Technology Innovation for Coast Guard Operations and Enhanced Fisheries Control', 2024.

[51] Protection Web, 'Leonardo's ATOS: A Game Changer for Border Surveillance?', 2025, https://www.protectionweb.co.za/technology-and-innovation/leonardos-atos-a-game-changer-for-border-surveillance/.

[52] Lena, 'Surveillance Technologies at European Borders - Assessment on Evros'; David Tashji, 'Nowhere To Hide | The AI Revolution in Surveillance & Targeting Sensors', 2024, https://pwkinternational.com/2024/03/25/no-where-to-hide-the-ai-revolution-in-surveillance-targeting-sensors/.

[53] National Cyber Security Centre, 'The Near-Term Impact of AI on the Cyber Threat', 2024.

[54] See https://www.frontex.europa.eu/innovation/announcements/industry-day-on-artificial-intelligence-tools-for-seamless-border-checks-at-european-border-crossing-points-lUTEhX

maintenance needs, and weather-related constraints.[55] Technical future advancements considered here to address these challenges include investing in next-generation sensor technology with enhanced accuracy, adopting predictive maintenance practices to reduce downtime, and integrating AI-powered algorithms to filter out false positives. Developing all-weather operational capabilities and leveraging public-private partnerships are also areas of future priority, with the aim to mitigate costs and improve overall efficiency. Moreover, the expansion of surveillance infrastructure has been criticised in the context of advocacy against "fortress Europe", where reinforced controls at the borders increase the risks for migrants during an irregular journey, as they are more likely to try more remote and dangerous routes or to employ smugglers, to avoid detection.[56] In this regard, research has suggested that such activities merely displace irregular migration flows (and make them more risky and expensive in the process), rather than prevent them.[57]

For Frontex, the potential for AI in their work is an area of future development. Indeed, a Frontex-commissioned study aimed at identifying areas where AI could be engaged to manage the EU's external border. While the study focused on technical solutions, it also highlighted the broader ethical questions surrounding AI-based surveillance, especially in regards to data privacy, the risk of discriminatory profiling, and the consequences of automated decision-making in border management.[58]

3.2 Risk analysis, Nowcasting, Early Warning, and Forecasting

As the migration landscape is becoming more complex and unpredictable, given recent trends highlighted in the previous chapter, new technologies and big data analysis used for forecasting and foresight are increasingly considered in border management and policy development. By combining AI-driven analytics and predictive modelling to strengthen monitoring systems, these tools aim to identify emerging displacement patterns, irregular migration flows, and asylum trends. These tools are engaged in migration management generally, and border management specifically, and aim to allow authorities to anticipate and prepare for migration flows and challenges effectively. In leveraging socioeconomic, geopolitical and other indicators, these predictive tools aim to enable border agencies and international organisations to proactively allocate resources, optimise reception capacities, and implement adaptive border management strategies. While these technologies improve foresight, they also raise important questions about accuracy, reliability, ethical implications, and their potential use in restrictive migration

[55] IEEE, 'High-Tech Border Security: Current and Emerging Trends', 2025, https://publicsafety.ieee.org/topics/high-tech-border-security-current-and-emerging-trends.
[56] Hannah Tyler, 'The Increasing Use of Artificial Intelligence in Border Zones Prompts Privacy Questions', *Migration Policy Institute*, 2022.
[57] ICMPD, ECRE Optimity Advisors, 'A Study on Smuggling of Migrants - Characteristics, Responses and Cooperation with Third Countries', 2015; Ruben Andersson, 'Europe's Failed "Fight" against Irregular Migration: Ethnographic Notes on a Counterproductive Industry', *Journal of Ethnic and Migration Studies* 42, no. 7 (27 May 2016): 1055–75, https://doi.org/10.1080/1369183X.2016.1139446.
[58] RAND Europe, 'How AI Can Support the European Border and Coast Guard', 2021, https://www.rand.org/randeurope/research/projects/2021/european-border-coast-guard-artificial-intelligence.html;%20https://www.migrationpolicy.org/article/artificial-intelligence-border-zones-privacy.

policies. Moreover, they are also considered quite critically, as a potential means to hinder migrants' (including refugees') access to a country's territory.[59]

Risk analysis management systems, based on the Common Integrated Risk Analysis (CIRAM)[60] model of Frontex plays an important role in border management by using data-driven methodologies, AI algorithms, and real-time intelligence to identify, assess, and mitigate potential threats. It takes a management approach to risk analysis, defining risk as a function of threat, vulnerability, and impact. This way, it reflects the spirit of the Schengen Borders Code and the European Border and Coast Guard Regulations.[61] By integrating AI, machine learning, satellite imaging, and real-time analytics, these tools provide actionable insights, and have transformed how border authorities operate, manage migration flows, and allocate sources more effectively. Key measures this approach has fed into include strengthening EU border checks at BCPs, enhancing surveillance of border sections, developing analytical tools (API, PNR), early warning, and foresight capabilities, and implementing crisis responses to address cases of migration instrumentalisation.[62] This underscores the critical role border agencies consider predictive systems can serve in mitigating potential destabilisation caused by irregular migration and external threats.

Early warning systems and the development of technologies for forecasting irregular migration flows or asylum seeker arrivals emerged from pre-frontier picture and border surveillance systems (e.g. the Spanish Guardia Civil's SIVE system). From irregular migration and cross-border smuggling to environmental disasters, border management has evolved to rely on advanced predictive technologies such as nowcasting, early warning systems (EWS), and forecasting models. While some early warning systems were in place pre-2015, following the European "migration crisis", they were prioritised as a means to better prepare for large-scale arrivals in the future, given the challenges faced. In the context of migration policy development, forecasting is considered a tool to support decision-making, not an end in itself. Thus, those interested in using forecasts (such as organisations) have been called to first understand their purpose, potential and also limitations, as they consider integrating such approaches.[63]

For the purpose of this paper, however, the aim is to examine the role of innovation in various border management-related areas. In this regard, new data sources are increasingly considered to improve forecasting models, given that traditional data sources may not be sufficient to anticipate future scenarios.[64] Examples of such innovations include satellite imaging for tracking movement patterns, AI-based tools for real-time analysis of migration trends, and machine learning algorithms that predict high-risk zones based on historical and real-time data. However, the increasing reliance on digital technologies for migration management also raises important

[59] Ecorys, 'Feasibility Study on a Forecasting and Early Warning Tool for Migration Based on Artificial Intelligence Technology', 2020.
[60] See https://www.frontex.europa.eu/what-we-do/monitoring-and-risk-analysis/ciram/
[61] Frontex, 'Monitoring and Risk Analysis'.
[62] Frontex, 'Strategic Risk Analysis 2024 Report'.
[63] IOM, 'Forecasting Global Migration', *MIGRATION POLICY PRACTICE*, 2020.
[64] ICMPD, 'AP2.D1 Deliverable', 2018.

considerations regarding privacy, data protection, and potential unintended consequences for fundamental rights. Moreover, the use of new data sources (such as social media or similar data) is also an area of concern, given the ethical and fundamental rights implications.[65]

In the area of forecasting and foresight, there are a wide range of systems that provide different time horizons of predictive analytics. An early warning system more broadly relates to various forms of hazard preparation and risk reduction. In the area of border management, one of the earliest examples from Europe of an early warning system was Spain's SIVE system. It was initially designed to tackle smuggler gangs using speedboats to dump drugs on the Spanish coast, so its design was for detecting small vessels travelling at fast speed. It was then adapted to detect irregular journeys from the Moroccan coast to the Canary Islands, where sensors were used to provide early warning, predict boats' estimated time of arrival, and even predict the number of people on board. Based on this, the Spanish Coast Guard and Guardia Civil would be able to deploy an interception or rescue unit.[66]

In Germany, following the large migration influx in 2015/2016, interest in quantitative predictions increased significantly. They began developing a machine-learning-supported crisis early warning instrument, then, following in 2020, they advanced it to their own machine-learning-based instrument 'Preview', which searches publicly available data for early signs of crisis. Yet, Germany, perceived as a pioneer of migration prediction in Europe, still had a gap: they had no systematic forecasting of forced displacement and irregular migration. However, BAMF is currently working on developing a new IT-based instrument for predictive migration analysis (medium term). This tool is set up to address gaps in forecasting forced displacement and irregular migration. What makes it distinct is its integration of advanced machine learning models with real-time data from multiple sources, including satellite imagery and social media trends. [67] This approach aims to allow it to quickly adapt to evolving migration patterns and provide granular insights, enabling targeted interventions.

Additionally, there is the Foresight model for forecasting which was developed by the Danish Refugee Council (DRC) and IBM with funding from the Danish Ministry of Foreign Affairs. This model uses the historical relationships and patterns in the data on 148 displacement-relevant indicators from 18 different open sources to forecast the total number of forcibly displaced people between one and three years into the future. This model has been used in 26 countries[68] to forecast the number of displaced people.[69] The DRC has been a pioneer in developing tools for

[65] Maegan Hendow et al., 'How Fit Is the Available Data on Irregular Migration for Policymaking? In MIrreM Policy Brief No. 3.' (Krems, 2024).
[66] Walter Kemp, 'Learning from the Canaries: Lessons from the "Cayucos" Crisis', 2016.
[67] Steffen Angenendt, Anne Koch, and Jasper Tjaden, 'Predicting Irregular Migration - High Hopes, Meagre Results', 2023.
[68] The countries are: Europe: Ukraine; Asia: Myanmar, Afghanistan; West Africa: Burkina Faso, Cameroon, CAR, Chad, Mali, Niger, Nigeria; MENA: Iraq, Libya, Syria, Yemen; East Africa & Great Lakes: Burundi, DR Congo, Ethiopia, Mozambique, Somalia, South Sudan, Sudan; Latin America: Colombia, El Salvador, Guatemala, Honduras and Venezuela.
[69] The Danish Refugee Council, 'Global Displacement Forecast 2024 - Using Data Modelling to Predict Displacement Crises', 2024.

displacement, additional models are the AHEAD (predicting numbers of displaced people in 3 to 4 months into the future), and SPIN (predicts number of threats in the coming months).

At the EU level there are similar developments. The SIVE system was considered by Frontex as a blueprint for its EUROSUR surveillance system. The European Union Agency for Asylum has also been proactive in developing its own early warning and preparedness system (EPS), which gathers data from relevant authorities. The EPS indicators focus on all key stages of the Common European Asylum System (CEAS).[70] This system was initially launched in 2012 to better understand asylum-related migration to the EU, Norway and Switzerland, to provide an information exchange mechanism aimed at providing timely, accurate and comparable data on the lodging and processing of asylum applications. The EPS data is considered the cornerstone of the EUAA analytical framework, and consists of four types of analytics (descriptive, diagnostic, predictive, and perspective). It also addresses different time horizons, including nowcasting and monitoring, early warning, and forecasting, by connecting current and past trends. Past events might guide future predictions, but factors of asylum-related migration might vary between migration flows or events.[71]

For forecasting, EUAA also engages the machine learning system DynENet, which integrates traditional migration and asylum data with data on conflicts and internet searches in potential asylum seekers countries of origin (based on big data).[72] By analysing internet searches in countries of origin, DynENet develops forecasts of asylum applications lodged in the EU up to four weeks in advance, and therefore presents an ability to identify emerging patterns and early indicators of potential migration flows.[73] There has also been an interest on the EU level in AI-based migration prediction, and this has also grown since 2015/2016; the EU has been investigating the potential for an EU-wide migration forecasting instrument. However, the ambition of developing a comprehensive forecasting and early warning system for irregular migration into the EU does present some limitations. On the one hand, even the most advanced AI-based instruments cannot yet adequately grasp the complex interaction of the numerous factors that influence migration decisions, and on the other hand, the reliability of any forecast is limited by the aleatoric uncertainty of migration processes.[74]

Given the considered potential of these systems for border and migration management, in 2021, the European Commission did a feasibility study on a forecasting and early warning tool for migration based on AI technology, to assess the capability of forecasting the direction and intensity of irregular migratory flows to and within the EU and to provide early warning and forecasts on the short term (from 1 to 4 weeks) and the medium term (from 1 to 3 months). Such

[70] EUAA, 'Early Warning and Preparedness System Data', 2024.
[71] Constantinos Melachrinos, Marcello Carammia, and Teddy Wilkin, 'AN INNOVATIVE FRAMEWORK FOR ANALYSING ASYLUM-RELATED MIGRATION', 2023.
[72] Tagliapietra, 'Technologies and Borders - The EU Is Digitalizing Migration Externalization'.
[73] EUAA, 'EUAA and European Commission Scientists Unveil Forecasting Model for Asylum-Related Migration, Based on Big Data', 2022, https://euaa.europa.eu/news-events/euaa-and-european-commission-scientists-unveil-forecasting-model-asylum-related-migration-based-big-data.
[74] Angenendt, Koch, and Tjaden, 'Predicting Irregular Migration - High Hopes, Meagre Results'.

a tool at the EU level is envisioned to function by incorporating and adequately processing data sources across all stages of the process of migration, starting with an assessment of the situations in third countries first, which would lead to early indications. Following, data on trends from previous movements along transit countries would be updated against the actual size of flows, and combined with data on the number of irregular migrants already present in the EU external border countries.[75]

Aside from this study, the EU has invested through its Horizon funding programme in a number of different research projects developing innovative approaches to forecasting. One example is the EUMigraTool developed by the ITFlows project, which aimed to predict migration flows to support humanitarian responses of civil society actors (forecasting). It did so through a small-scale model using a simulation development approach, as well as a large-scale forecasting model using machine learning. Another example of an EU-funded project advancing research in this area was the HumMingBird project, which tested new methods to forecast emerging and future trends. For example, for predicting performance, their machine learning model outperformed the traditional auto-regressive AR (1) models, both in training and testing phases. Their model allowed for a deeper understanding of the complexity of migration, but also the potential of innovative data integration and analytical techniques in improving the predictability of migration patterns.[76] JETSON, another similar model to the DRC models noted above, was developed by UNHCR as a machine learning-based experiment that provided predictions on the movement(s) of displaced people. It combined data science, statistical processes, design-thinking techniques, and qualitative research methods all together. Its aim was to enable UNHCR among other humanitarian organisations to become more proactive in emergency preparedness by anticipating displacement trends.[77]

More recently, the OECD has created a taskforce on migration anticipation and preparedness (MAP), which is at the time of writing gathering an overview of forecasting practices across 15+ countries. Their work will establish inventory of existing tools/methods, identify innovative practices, and implement and test methodologies synthesising the gathered information in a final handbook. The final OECD study is forthcoming in 2025 and should provide state of the art lessons on methods and approaches to forecasting across the OECD countries under study.

Building on these insights, innovative approaches like nowcasting have emerged to address the need for real-time predictions, as a more operational approach to provide foresight before departures (early warning), yet more practicable. Nowcasting has also emerged as a powerful tool to make real-time predictions and assessments across various industries. It is a process whereby it predicts the present, the very near future, and compare it with past data. Contrary to

[75] Ecorys, 'Feasibility Study on a Forecasting and Early Warning Tool for Migration Based on Artificial Intelligence Technology'.
[76] Ides Nicaise and Tuba Bircan, 'Anticipating and Managing Migration Flows towards the EU - HumMingBird Synthesis Report', 2024.
[77] See https://jetson.unhcr.org/

traditional methods that only depend on historical data to make long-term predictions, it rather focuses on immediate insights based on real-time data.[78]

While investments in prediction technologies provide valuable tools for anticipating trends, allocating resources, and preparing for migration challenges, their use also raises myriad concerns and their limitations should also be underlined. Despite promising a certain level of precision and reliability, their practical utility to date falls short of these hopes. While these tools based on machine learning typically gather group-based rather than individual data, this still entails human rights risks. For example, in the context of the overheated and polarised debate about forced displacement and migration, predictions are inherently political, and this could lead to a risk of creating threat scenarios and stoking fear. The result of this could lead to closure of border crossings or to an increase of racist attacks against a particular group.[79] Given these risks, use of these systems in the area of border management are an area of increasing concern for civil society and fundamental rights advocates.

3.3 Database management and interoperability

Data collection, interoperability, and emerging technologies in these fields are also shaping border and migration management. This section explores how biometric and alphanumeric data is collected, processed and shared across national and EU systems, the role of interoperability in linking databases, and the impact of these technologies on migration governance. It also considers concerns related to data protection and privacy. For border management, collected data is considered key. As noted in the previous sections, border surveillance and pre-screening, risk analysis and forecasting all require different forms of data collection and processing, for operational purposes. In addition, identity-based data collection has become increasingly central to border and migration management systems – the "datafication" of migration.[80] In this context, states are not alone in collecting data – EU agencies like Frontex and international actors like IOM are increasingly central.[81]

Databases are considered vital to the migration management process: biometric and alphanumeric data is collected from visa applicants, during all processes during the border check procedures at the BCPs (including Entry/Exit systems), from risk analysis products (RAU

[78] Francesca Tabor, 'Nowcasting with AI: Revolutionizing Real-Time Predictions Across Industries', 2024.
[79] Steffen Angenendt and Anne Koch, 'Migration Forecasting: Expectations, Limitations and Political Functions', Forced Migration Review, 2024.
[80] Philippe M. Frowd, 'The "Datafication" of Borders in Global Context: The Role of the International Organization for Migration', *Geopolitics*, 21 February 2024, 1–19, https://doi.org/10.1080/14650045.2024.2318580; Matthias Leese, Simon Noori, and Stephan Scheel, 'Data Matters: The Politics and Practices of Digital Border and Migration Management', *Geopolitics* 27, no. 1 (1 January 2022): 5–25, https://doi.org/10.1080/14650045.2021.1940538; Ana Valdivia et al., 'Neither Opaque nor Transparent: A Transdisciplinary Methodology to Investigate Datafication at the EU Borders', *Big Data & Society* 9, no. 2 (21 July 2022), https://doi.org/10.1177/20539517221124586.
[81] Nina Amelung, Stephan Scheel, and Rogier van Reekum, 'Reinventing the Politics of Knowledge Production in Migration Studies: Introduction to the Special Issue', *Journal of Ethnic and Migration Studies* 50, no. 9 (27 May 2024): 2163–87, https://doi.org/10.1080/1369183X.2024.2307766.

reports), and from asylum applicants. Yet, from the perspective of some state actors, a key gap was the ability to compare data across these different databases. In the European context, thus, in parallel with the expansion of IT systems and databases to collect data across different forms of mobility, has been the establishment of the interoperability framework to connect these systems. Proponents of interoperability argue that it enhances efficiency and security in border control by facilitating the integration and sharing of biometric data across multiple databases within systems such as the Entry/Exit System (EES). They contend that this allows border guards to quickly determine whether an individual is already registered in another database such as the Visa Information System (VIS) for visa holders, or whether they pose a security risk as flagged by systems like the Schengen Information System (SIS) or the European Criminal Records Information System for Third-country nationals (ECRIS-TCN).

Additionally, security-focused arguments are also at the forefront, where authorities consider that interoperability will allow access to data that would help prevent fraudulent activities and reduce security risks more effectively, for example, the use of a multiple identity detector enables the identification of individuals across databases, helping to detect fraudulent IDs. The new Common Identity Repository (CIR), established by a new EU Regulation, is designed to store and manage biometric data (such as fingerprints and facial images) and alphanumeric information of non-EU nationals, with the aim to support effective identity management and enhanced border control by allowing EU Member States to share and cross-check data in real time. The CIR thus aims at supporting security and border-related goals, such as ensuring accurate identification, improving security, and facilitating efficient visa, asylum, and migration procedures while reducing the risk of identity fraud. This interoperability also aims to support risk analysis and policy development by enabling authorities to use data for enhanced screening procedures.[82]

All EU Member States (except Ireland) and four Schengen associated countries (Iceland, Liechtenstein, Norway, and Switzerland) participate in the interoperability regulations. These IT systems are the Schengen Information System II (SIS II), the European Dactyloscopy Database (Eurodac) and the Visa Information System (VIS). Soon to also be implemented are the Entry/Exit System (EES), the European Travel Information and Authorisation System (ETIAS) and the European Criminal Records Information System on Third-Country Nationals (ECRIS-TCN),[83] more details on these will be discussed in the following section.

While these systems represent large-scale data collected at the EU level, database development is also significant for the national level. Here, partners are also integral to development of IT systems tailored to national needs. For example, the Migration Information and Data Analysis System (MIDAS) was developed by IOM to support States with fewer data capture systems, in

[82] European Comission, 'Interoperability of EU Information Systems for Security, Border and Migration Management', 2017, https://ec.europa.eu/commission/presscorner/detail/fr/memo_17_5241; EU-LISA, 'Interoperability', 2025, https://www.eulisa.europa.eu/activities/interoperability.
[83] European Commission, 'Interoperability', 2024, https://home-affairs.ec.europa.eu/policies/schengen-borders-and-visa/interoperability_en.

order to support their migration management approach.[84] This system supports a range of functions including: regularisation, readmission, a comprehensive and affordable border management information system management, passenger data (API/PNR), border and migration management assessments, border security, integrated border management, border and migration management policy, counter-migrant smuggling, community policing, travel document inspection and identification, among others.[85]

Within the accession process, development of national systems to link up to the EU ones is also considered a key area. Within the EU Serbia Stabilisation and Accession Agreement, for example, is a five-year strategy aimed at enabling national interoperability with EURODAC, as well as aligning with the EU Dublin Regulation and EU visa policies. This approach highlights the ongoing efforts to integrate newer member states and neighbouring countries into the EU's broader security framework. This partnership is considered particularly significant in the context of the Western Balkans route, where managing migration is a priority for the EU due to the complex dynamics of migration flows in this region.[86]

Looking to the future, the EU has been exploring cutting-edge technologies like blockchain to further enhance interoperability and secure the exchange of sensitive information. This exchange of highly sensitive information connects different services and systems with the aim to improve information flow across stakeholders. Blockchain allows the interoperability of services, and the sharing of information confidentially among relevant authorities in an integral manner.[87] Germany has been at the forefront of piloting this technology, through its federal asylum blockchain infrastructure FLORA since 2021. This new blockchain based supports cooperation between authorities involved in the asylum procedure, improving processes and reducing the possibility of processing errors. It is expected to lead to a more rapid exchange of information, shortening procedure times and saving resources. It does not replace any existing systems but will support connecting systems together to improve information flows. The system is already operational in four federal states and is in the process of expanding to other federal states. An evaluation of the system suggested that it has reduced instances of fraud by ensuring data integrity and providing immutable transaction records. It works like a "magical notebook", wherein once information is written in the notebook, it cannot be erased or changed unnoticed. It has thus been considered a secure and reliable source for information sharing and process automation, and is unique for its adaptability, or technological flexibility to adapt to local and changing requirements over time. [88] Moreover, France is also adopting a similar project between the Asylum Department of the Ministry of Interior and the ANEF portal (Digital Administration for Foreign Nationals in France).

[84] IOM, 'Immigration and Border Management', 2024.
[85] See https://lac.iom.int/en/immigration-and-border-management
[86] Hatchwell and F, 'Surveillance Technologies at European Borders - An Assessment of Serbia'.
[87] EMN-OECD, 'THE USE OF DIGITALISATION AND ARTIFICIAL INTELLIGENCE IN MIGRATION MANAGEMENT', 2022, https://www.oecd.org/content/dam/oecd/en/topics/policy-issues/migration/EMN-OECD-INFORM-FEB-2022-The-use-of-Digitalisation-and-AI-in-Migration-Management.pdf.
[88] Federal Office for Migration and Refugees - BAMF, 'The Federal Asylum Blockchain Infrastructure', 2022.

Given these developments, civil society and data protection and privacy advocates have expressed serious concerns around the large-scale collection of personal data, as well as the access to these data by law enforcement authorities. The expansion of databases beyond their initial purpose, epitomised in the development of the Eurodac database's scope from asylum only to all irregular migrants identified on EU territory, presents concerns about "function creep".[89] In this context, the development of new databases to collect more data, for example the Entry-Exit System, has been criticised by EU and national data protection advocates for its potential violation of data protection principles. Civil society, meanwhile, have expressed concerns that such systems could underpin control systems and surveillance within EU territory, with the potential for contributing to more draconian detention and deportation systems, as well as associating travellers and migrants with crime and terrorism.[90] Concerns also exist at the operational level. One consideration is the high number of technical experts needed to develop and maintain these systems, who will have to work closely with end-users (police and border officers), but also the specific training needed on how to collect and register data in coherent and understandable way by all member states.[91]

3.4 Process facilitation

While the previous sections highlight relevant developments in technology related to detecting irregular migration as part of border management priorities, facilitation of travellers' mobility is another major area of work in which technology plays an important role, and which will be examined in this section. Border management authorities increasingly rely on biometric authentication, AI-driven identity verification, and automation to streamline border crossing processes while maintaining security. New technologies also provide new tools at the disposal of border guards in the identity verification process. Biometric authentication innovations such as automated border controls have already been observed at airports, which include all stages of cross-border movement from pre-departure to exit, but have also been tested at land and maritime borders. Given the large passenger flows and controlled environment (away from natural elements), airports have tested a wide range of new technologies, including AI, to facilitate passengers' mobility through border controls. Reaching a contactless travel experience is also an aim for the future for border management stakeholders.

Firstly, border agencies have turned to new technologies to support them in the document and identity verification processes. These technologies aim to address specific challenges, such as reducing wait times for travellers at border crossings and enhancing fraud detection capabilities. For instance, proponents argue that automated biometric systems streamline identity checks, while advanced AI tools can help identify fraudulent documents or inconsistencies in traveller information with greater accuracy and speed. There have been several advancements in identity

[89] EU-LISA, 'Eurodac', 2025, https://www.eulisa.europa.eu/activities/large-scale-it-systems/eurodac.
[90] Hendow et al., 'How Fit Is the Available Data on Irregular Migration for Policymaking? In MIrreM Policy Brief No. 3.'
[91] Cristina Blasi Casagran, 'Fundamental Rights Implications of Interconnecting Migration and Policing Databases in the EU', *Human Rights Law Review* 21, no. 2 (12 March 2021): 433–57, https://doi.org/10.1093/hrlr/ngaa057.

verification and fraud detection, especially while integrating biometric technologies, AI, and digital identity frameworks. One example is the EU-funded D4FLY project, which has developed innovations in biometric recognition methods namely 3D-Face, Iris on-the-move, thermal-to-visible and somatotype verification. Additional progress beyond the state of the art is the advancements in counter spoofing and attack detection technologies, especially liveliness detection technology and detection of manipulated images, as well as in document verification technologies (extending the know-how on automatic detection and verification of document security elements). Their prototypes have been tested in the UK, Lithuania, Greece, and the Netherlands, and have been implemented in the UK (highly automated border post and coach scenario), and in the Netherlands (document verification).[92]

AI is increasingly being used to tackle identity fraud and improve language assessment in migration processes. For instance, in Germany, BAMF uses an AI tool called DIAS, which is the language and dialect identification assistance system, that can differentiate between different dialects to confirm the country of origin, particularly useful in secondary border controls. To identify fraud detection, several EU countries are also deploying new technologies. The Netherlands for instance uses algorithms to support examination and detection of document fraud related to breeder documents. In Finland, a project being piloted called TIKKA seeks to confirm identity of applicants through a combination of open-source data, AI and human analysis. Hungary and Lithuania have also used or tested AI for facial recognition. The Aliens Policing Authority in Hungary uses facial recognition to identify foreign nationals and prevent fraud, while in Lithuania, in 2021 the State Border Guard Service participated in a field test trying out different AI solutions for land border checks. The technologies developed for verification and detection included 3D facial and iris verification techniques.[93]

While these technologies have significantly enhanced border security and fraud detection, they are not without challenges. Criminals have found a way to go unnoticed by these technologies, by creating untrustworthy face images through a 'morphing' attach to hide their real identity. Morph attacks usually blend the facial images of two people, so that the morphed image can be used to verify both individuals; usually the criminal who wants to pass a border morphs his face with another person that resembles them but has a clean record. Potential solutions to counter morphing attacks include the deployment of advanced anti-spoofing algorithms, 3D facial recognition technology, and AI-driven analysis that can detect subtle discrepancies in morphed images. Additionally, multi-modal biometric verification, combining facial recognition with iris or fingerprint data, is increasingly considered a means to counter morphing.[94]

For Europe, a major advancement in this area will be the implementation of the European Travel Information Authorisation System (ETIAS), to support the identity verification process for border control before an individual's departure. This system will require the pre-registration of visa-

[92] For more information see https://d4fly.eu/about-d4fly/the-project-2/
[93] EMN-OECD, 'THE USE OF DIGITALISATION AND ARTIFICIAL INTELLIGENCE IN MIGRATION MANAGEMENT'.
[94] Chuo Jun Zhang et al., 'AI-Based Identity Fraud Detection: A Systematic Review', 15 January 2025.

exempt visitors travelling to the Schengen area (biographic, passport and travel data), will assess any security or irregular migratory risks based on the data provided, according to screening guidance, and will issue a Travel Authorisation (TA) for the applicants.[95] Applying for ETIAS will be done either through their online platform or through the mobile application, and is planned to take minutes to be processed, and up to 14 days in some cases.[96] Given the risks to fundamental rights in the development of screening rules in processing these applications, ETIAS has a Fundamental Rights Guidance Board to regularly review the process, issue recommendations and provide guidance where needed in the development of ETIAS screening rules and risk indicators, especially as related to privacy, data protection and non-discrimination.[97] Receiving this authorisation also does not automatically mean the person will be granted entry, a border guard will still ask to see the traveller's passport and other documents to verify the entry conditions, yet as the information will have already been provided through ETIAS, the processing of the traveller during border control would be facilitated. Visa-free travellers will also be asked to provide biometrics on arrival, with the information provided in ETIAS then able to be connected to the Entry-Exit System under the interoperability framework.

Together with ETIAS, the Entry/Exit System (EES) and related amendment to the Schengen Borders Code is considered to also improve border control across the EU, as it will automate the calculation of stay (i.e. 90 out of 180 days for short stay). The key objectives of the EES are to reinforce the efficiency of border management, to prevent irregular migration, to facilitate the management of migration flows, to identify travellers who have no right to enter or who have exceeded their stay and, within the interoperability framework, to identify fake IDs or passports held by travellers, and to prevent and detect terrorist offences and other crimes.[98] The EES will register the biometrics of non-EU nationals travelling for a short stay (visa free and Schengen visa holders), as well as name, type of travel document, and location and date of entry (and exit). In doing so, the system aims to identify those who may overstay their permission to stay.[99] The system will be applied in 25 EU countries (apart from Cyprus and Ireland), and four non-EU

[95] VFS Global, 'Enhancing Border Management Systems Using Artificial Intelligence'.
[96] European Union, 'What Is ETIAS', 2024, https://travel-europe.europa.eu/etias/what-etias_en.
[97] The Fundamental Rights Guidance Board includes members from: the Fundamental Rights Officer of the European Border and Coast Guard Agency (the "agency"), a representative of the Consultative Forum on Fundamental Rights of the agency, a representative of the European Data Protection Supervisor, a representative of the European Data Protection Board, and a representative of the European Union Agency for Fundamental Rights.
[98] European Union, 'What Is the EES?', 2024, https://travel-europe.europa.eu/ees/what-ees_en; European Union, 'Data Held by the EES', 2024, https://travel-europe.europa.eu/ees/data-held-ees_en; European Union, 'Key Differences between ETIAS and the EES', 2025, https://travel-europe.europa.eu/key-differences-between-etias-and-ees-2025-01-09_en.
[99] European Commission, 'Entry/Exit System (EES)', 2024, https://home-affairs.ec.europa.eu/policies/schengen-borders-and-visa/smart-borders/entry-exit-system_en.

countries (Norway, Iceland, Switzerland and Lichtenstein), thus aims to set up a uniform process across the EU's external borders.[100]

Although the system has faced many delays, it is now planned to be rolled out in 2025 in a phased approach. The implementation of an additional process in border control is a concern of many border management stakeholders, given the additional burden (and time required) to register biometrics across all border crossing points. However, retention of biometric data (for three years or five years, in the latter case if an exit is not recorded) means that re-registration of data is not required at each entry, facilitating frequent passengers' travel in subsequent trips. At the central level as well, the operationalisation of this system will need to be seamless in order to function properly, which was a key reasoning for the most recent delay.

What are the key differences between ETIAS and EES? These two border management initiatives that will be launched by the EU in 2025 aim to strengthen border security in particular, but also have implications for migration management more broadly.[101]

ETIAS	EES
New entry requirement for travellers who do not need a visa to enter 30 European countries	Will register visa-free and visa-required travellers entering 29 countries
Short stay travellers	Short stay travellers
Visa-free travellers need to apply for a travel authorisation before the trip	No action is required from travellers before the trip
It is not a visa	It is not a visa
Collects personal information (address, passport details, occupation)	Collects travel document data & date and place of entry and exit
No biometrics data collected	Collects facial image and fingerprints
Need to apply well in advance	Registration is at the border crossing point
ETIAS will follow few months after EES	EES will operate first
Data held for five years from the last decision to refuse, annul, or revoke the TA	Data held for three years for all, five years for those for whom no exit is detected

In the area of process facilitation, there have also been noticeable advancements in e-Gates or automated border controls. Now ubiquitous across European airports, they aim to streamline border crossing by automating identity checks, speeding up the process and reducing burdens on border guards. The Netherlands, for example, have deployed 78 e-gates at their Amsterdam Airport Schipol. They have dedicated a whole site for travellers with instructions on how to use them, how to stand, where to face, and to remain still until the system confirms their image

[100] Stefano Fella, 'The EU Entry/Exit System and EU Travel Authorisation System', House of Commons Library - UK Parliament, 2024, https://commonslibrary.parliament.uk/the-eu-entry-exit-system-and-eu-travel-authorisation-system/#:~:text=This%20will%20replace%20the%20current,place%20of%20entry%20and%20exit.
[101] Hendow et al., 'How Fit Is the Available Data on Irregular Migration for Policymaking? In MIrreM Policy Brief No. 3.'

capture.[102] E-gates also highlight the speed at which technology is developing, currently in the third generation at least. In Norway, for example, they are already looking to update their e-gates, which are reaching the end of their first-generation lifecycle.[103]

Innovative developments outside Europe also include efforts to improve border control through the use of e-gates with biometric authentication technology, as is for example used in the Biometric Immigration System at Chennai Airport, in India.[104] Similarly, the Smart Travel Project at Zayed International Airport in Abu Dhabi plans to implement biometric sensors at every identification checkpoint in 2025. This system relies on the partnership with the country's Federal Authority for Identity, Citizenship, Customs and Port Security, which collect biometrics from any traveller arriving in the UAE for the first time, and then the airport may use this database to verify passengers at checkpoints.[105] The UAE is aiming to position itself on the forefront of such developments, such as with Dubai's Smart Tunnel project,[106] which showcases how machine learning and biometric recognition are revolutionising the travel experience beyond e-gates, reducing reliance on traditional documents. This project, which was piloted in 2018, uses machine learning to assess its passengers' data as part of the transit process, without using any travel documents or boarding passes. While passengers are still required to pre-register their data, they were then able finish passport control procedures in less than 15 seconds, with the traveller passing through a tunnel and facing a camera equipped with biometric recognition technology (facial image, iris). Dubai ran this project along with their existing smart gates system, which uses facial recognition software, allowing residents to use their Emirates ID or registered passports to pass through without any encounter with passport control officers.[107]

Moreover, research and innovation are ongoing in this area, with the EU funding projects piloting new features in automated border control. The project iBorderCtrl, for example, tested the use of automated lie detection technology in Greece, Hungary and Latvia. In the project, travellers were asked about their countries of origin and reasons for traveling, and the answers evaluated by an AI-based lie-detecting system. The science behind it is a technology called 'affect recognition science', which reads facial expressions and infer emotional states in order to reach legal judgements or policy decisions.[108] Outside the EU, in Lebanon they have integrated the secure border management system (sBMS) solution on all 3 borders (airport, land ports, and seaports). Unlike the conventional border control systems, the sBMS includes a comprehensive suite of components including high-end document verification, full biometric matching tool for

[102] Royal Netherlands Marechaussee, 'Self-Service Passport Control (EGates)', 2024, https://english.marechaussee.nl/topics/self-service-passport-control.
[103] Tech, 'Norway Seeks E-Gate Info for Automated Border Control in 2025', 2024, https://idtechwire.com/norway-seeks-e-gate-info-for-automated-border-control-in-2025/.
[104] Tech, 'Chennai Airport to Launch Biometric Immigration System in 2025, Cutting Processing Time by 60%', 2025.
[105] Kevin Williams, 'The World's First Airport to Require Biometric Boarding Is Set to Arrive in 2025', *CNBC*, 2024.
[106] Tyler, 'The Increasing Use of Artificial Intelligence in Border Zones Prompts Privacy Questions'.
[107] VFS Global, 'Enhancing Border Management Systems Using Artificial Intelligence'.
[108] Feldstein, 'The Global Expansion of AI Surveillance'.

data comparison, automatic control list and INTERPOL queries, entry/exit system, online data replication between HQ and all borders, alarm and reporting intelligence, and tracking of all movements (entering and exiting the country).[109]

Beyond biometric solutions, the Electronic Visa (E-Visa) is also becoming ubiquitous as a service in the travel domain and is a relevant development across EU Member States. It offers travellers the possibility to apply for their visa online, using secure solutions. After filling out an online application, AI and digital quality checks are performed to ensure that all the details entered are correct, and all required documents are uploaded. The e-visa is considered convenient for travellers, but also supports governments to process visa decisions faster with the help of a digitised platform in a secure (GDPR and data privacy compliant) format.[110] Many EU countries, including the Czech Republic, Lithuania, France, the Netherlands, Sweden already use electronic processes, as do non-EU countries such as Australia, Canada, Chile, India, Kenya, New Zealand, Singapore. For example, in Australia, online visa applications are made through ImmiAccount (an online platform for creating, submitting and managing visa applications), while they have also launched the ETA (Electronic Travel Authority) visa mobile app for selected nationalities. In the EU, digital systems are mainly used for lodging applications remotely, and while some countries have completely digitised the process, others rather engage it in only part of the process. For example, in Lithuania documents and applications are submitted through the Lithuanian Migration Information System (MIGRIS), but travellers still need to present the original documents in person at the appointment.[111]

Another example, Estonia, who has implemented the ABIS system (Automated Biometric Identification System database), which is a central national database where biometric data gathered in state proceedings is stored (facial and fingerprint images and palm prints). It allows for the comparison of biometric data using AI, to verify personal identification and identity. According to official documents, data is processed in compliance with all the data protection principles and requirements, to ensure lawful and transparent use of data including GDPR. However, once data is submitted to the system, an individual is not permitted to request its erasure from ABIS, and this also raises concerns on how it is not compliant with data protection.[112]

As with all areas where new technologies have been engaged in border control, there are also ethical and fundamental rights concerns related to the use of biometrics. Some critics highlight the potential for its use in for example travel documents to increase the digital divide between

[109] European Commission, 'Action Document for "Support to Integrated Border Management in Lebanon"', 2023, https://neighbourhood-enlargement.ec.europa.eu/document/download/1e0545ad-b425-4a25-bb09-e03168c5a110_en?filename=C_2023_7519_F1_ANNEX_EN_V1_P1_3023893.PDF.
[110] VFS Global, 'Enhancing Border Management Systems Using Artificial Intelligence'.
[111] EMN-OECD, 'THE USE OF DIGITALISATION AND ARTIFICIAL INTELLIGENCE IN MIGRATION MANAGEMENT'.
[112] Ministry of Interior - Republic of Estonia, 'Automated Biometric Identification System Database ABIS', 2025, https://www.siseministeerium.ee/en/abis#is-abis-in-conformit.

those who can access and afford such new processes, and those who cannot.[113] Other concerns include the inconsistencies and incoherence in border practices, while the standardisation and use of new technologies in border management represents to some critics a securitisation of mobility, particularly in the context of national security and the governance of irregular migration. While new technologies aim to enhance security, their implementation within automated border control, such as e-gates, biometric passports, and registered traveller programmes, also introduce new challenges. They often promise greater freedoms for certain travellers, emphasising speed and efficiency, yet paradoxically equate these freedoms with increased control. This can be considered to shift the balance between security and freedom itself, raising critical concerns about its broader implications for mobility and human rights.[114]

4. Implications for policymakers: strategies, opportunities, and challenges

Advances in border management and modernisation technologies have transformed the way nations manage security, mobility, and trade at their frontiers. For instance, biometric systems, AI-driven surveillance, and big data analytics are used to increase efficiency and risk assessment; however, as noted before, their adoption also raises operational, policy, and ethical concerns. While these technologies enhance border management capabilities, they also present challenges related to data protection, governance, and potential biases. Therefore, a clear vision and a strong political will and commitment are required to achieve comprehensive border management reform.[115]

Throughout the paper, while discussing the different innovations in border management, their usage and advantages have been highlighted, together with their limitations. In this section, the aim is to stress upon the strategies, opportunities, and challenges that policymakers encounter in this domain. When thinking of border management reform, it is important to factor in likely operational challenges as well, such as insufficient physical, technical and financial resources, lack of specific policies/regulations, lack of experience in alternative regulatory environments among senior managers, lack of implementation capacity in government agencies or in the private sector. Moreover, issues such as outdated organisational structures and corruption (e.g. bribery) pose additional hurdles. To implement technological innovations successfully, border management agencies must secure political, institutional and financial commitment while assessing and strengthening administrative capacities.[116]

National AI strategies are one area that have gained traction: starting to be adopted since 2017, by 2023 there are reportedly 51 formalised national AI strategies as reported by the OECD AI Observatory. These strategies underscore the growing recognition among countries of the

[113] Elin Palm, 'Conflicting Interests in the Development of a Harmonized EU E-Passport', *Journal of Borderlands Studies*, June 2016, 1–16, https://doi.org/10.1080/08865655.2016.1181982.
[114] Albert Kraler, Maegan Hendow, and Ferruccio Pastore, 'Introduction: Multiplication and Multiplicity—Transformations of Border Control', *Journal of Borderlands Studies*, 2016.
[115] European Parliament, 'Artificial Intelligence at EU Borders - Overview of Applications and Key Issues'.
[116] See https://www.frontex.europa.eu/assets/Key_Documents/IBM/EU_IBM_Brochure_EN.pdf

importance of leveraging AI. However, policymakers must collaborate with stakeholders, such as the private sector, academia, and civil society, to align technological advancements with social and economic needs. Yet, the rapid pace of technological developments comes with its own challenges. Policymakers find it difficult to develop policies at speed, especially in situations of uncertainty and controversial technology fields.[117]

Within the context of these regulatory and legal developments and challenges, the integration of new technological tools, including AI, into policymaking processes introduces new opportunities, alongside further challenges related to data reliability and ethical concerns. AI systems, as already mentioned, are used or considered increasingly to analyse extensive data sets, ranging from financial transactions and watch lists to data from regional unions, and international organisations like INTERPOL. With the development of new large-scale IT systems for the EU with massive amounts of data, the potential of AI in this area is clear. Yet, how effective any analysis of this data is, only depends on the quality of the data it utilises.[118] For example, incomplete or biased data can lead to discrimination or lead to inaccurate risk assessments. Some forms of discrimination could be profiling people based on certain behavioural and demographic characteristics, and the fact that AI and algorithmic systems lack transparency complicates the detection of such discrimination.[119]

The EU AI Act has been the first attempt to regulate AI technologies, and make sure they are being developed under clear legal and ethical standards across the EU. Specific provisions include categorising AI systems by risk levels (minimal, limited, high, and unacceptable), with high-risk systems (of which their use in border control is one) subject to strict requirements on the use of AI, such as transparency, human oversight, and robustness testing. The EU AI Act requires providers of high-risk AI systems to disclose key characteristics of their models, including the training data, model architecture, and performance metrics.[120] This legal framework is what makes Europe stand out from other countries and territories, as it not only incorporates the opportunities that these technologies bring in, but also address their risks and challenges. Moreover, the European Commission has developed the AI Strategy, approved the AI Act, and has been following the Ethics Guidelines for Trustworthy AI since 2019.[121] Yet there are still challenges such as the lack of harmonisation across Member States, which leads to fragmented implementation and regulatory inconsistencies, and challenges to equality and non-

[117] OECD, 'Technology Policy', 2024, https://www.oecd.org/en/topics/policy-issues/technology-policy.html.
[118] Erdal Düzdaban, 'AI in Border Management: Implications and Future Challenges', 2024.
[119] FRA, 'Bias in Algorithms – Artificial Intelligence and Discrimination'; FRA, 'Data Quality and Artificial Intelligence – Mitigating Bias and Error to Protect Fundamental Rights', 2019.
[120] EU Artificial Intelligence Act. European Parliament legislative resolution of 13 March 2024 on the proposal for a regulation of the European Parliament and of the Council on laying down harmonized rules on Artificial Intelligence (Artificial Intelligence Act) and amending certain Union Legislative Acts [COM(2021)0206—C9-0146/2021-–2021/0106(COD)].
[121] European Commission, 'AI for Interoperability', 2024.

discrimination from increased digitisation.[122] Another challenge is addressing ethical concerns in relation to AI, as AI can tend to breach the right to be treated with dignity, such as mitigating biases in algorithms. They can also undermine rights if no attention has gone into this while developing the technologies and making sure they are in line with international human rights obligations.[123]

To this, the Commission has proposed three inter-related legal initiatives that will contribute to building trustworthy AI: a European legal framework for AI that upholds fundamental rights and addresses safety risks specific to the AI systems; a civil liability framework that adapts liability rules to the digital age and AI that has been adopted in October 2022; and a revision of sectoral safety legislation (for example machinery regulation, and general product safety directive).[124] Additionally, the Council of Europe also started working on AI in 2019, and in 2022 formed the Committee on Artificial Intelligence. This committee constitutes of multi-stakeholders that negotiate the Council's treaties as part of its practices, including civil society and industry representatives. Their framework was unanimously adopted in 2024 at the ministerial session of the Committee of Ministers of the Council and was signed by a number of countries. The focus of this framework is to formulate fundamental principles and rules which are conducive to progress and technological innovations, as well as safeguard human rights, democracy and the rule of law. This is crucial as it aims at filling in any legal gaps that may have formed due to the rapid technological advances.[125]

In addition to addressing global regulatory and ethical concerns, policymakers must also confront the technical challenges posed by AI systems. One of the most critical implications for policy makers is the need to address the so-called 'black box' problem, where AI systems operate with a level of opacity that makes it difficult to trace decision-making processes. This raises critical legal and ethical concerns due to their black box nature,[126] and about their impact on individual and societal well-being. In brief, a black box is explained as: as AI algorithms become increasingly sophisticated and autonomous, their decision-making processes can become opaque, making it difficult for individuals to understand how these systems are shaping their lives. This lack of transparency, as well as the possibility of biases has led to calls for greater accountability in AI governance in line with fundamental rights (particularly the rights to effective remedy, enshrined under the EU Charter of Fundamental Rights, and the right to explanation,

[122] European Commission, 'WHITE PAPER On Artificial Intelligence - A European Approach to Excellence and Trust', 2020.
[123] OSCE, 'Human Rights Risks of Using of New Technologies in Border Management Need Urgent Attention, International Human Rights Office ODIHR Says', 2024.
[124] European Commission, 'European Approach to Artificial Intelligence', 2024, https://digital-strategy.ec.europa.eu/en/policies/european-approach-artificial-intelligence#:~:text=A%20European%20legal%20framework%20on%20AI&text=The%20AI%20Act%20has%20a,for%20general%2Dpurpose%20AI%20models.
[125] Council of Europe, 'THE COUNCIL OF EUROPE & ARTIFICIAL INTELLIGENCE', 2024, https://rm.coe.int/brochure-artificial-intelligence-en-march-2023-print/1680aab8e6.
[126] Thomas Wischmeyer, 'Artificial Intelligence and Transparency: Opening the Black Box', in *Regulating Artificial Intelligence* (Cham: Springer International Publishing, 2020), 75–101, https://doi.org/10.1007/978-3-030-32361-5_4.

under the GDPR).[127] Specific methods to address this include the use of explainable AI tools that provide transparency by detailing the factors influencing decision-making. Technologies such as visual dashboards and model interpretability can help policymakers understand and audit AI decisions.[128]

Research says that the use of AI could lead to a digital divide.[129] Historically, this meant physical access to technology, but recently, this more reflects digital skills and their application, as with the widespread use of AI and its language models, more digital literacy issues are being witnessed.[130] However, this not only encompasses AI, but also includes digital infrastructure and innovations generally.[131] According to OECD, the digital divide exists along a range of dimensions, and that includes geography, education, age, income,..etc. Closing this gap is crucial to have a more inclusive digital future.[132]

In a nutshell, the use of modern technologies in border management presents challenges that policymakers must also consider, such as ensuring policies are compliant with legal frameworks, particularly on fundamental rights, assessing cybersecurity risks, taking into account high implementation and maintenance costs, addressing operational difficulties such as ensuring technological interoperability and staff resistance to change and skills gaps. All of this occurs within also a wider context of desire for continuous adaptation to emerging threats, and challenges in maintaining public trust and transparency, while also facing the ongoing burden of sustaining and updating systems to ensure they remain effective and secure.

[127] Ben Chester Cheong, 'Transparency and Accountability in AI Systems: Safeguarding Wellbeing in the Age of Algorithmic Decision-Making', *Frontiers in Human Dynamics* 6 (3 July 2024), https://doi.org/10.3389/fhumd.2024.1421273.
[128] Mardi Witzel, Gaston H. Gonnet, and Tim Snider, 'Explainable AI Policy: It Is Time to Challenge Post Hoc Explanations', 2024.
[129] United Nations, 'Mind the AI Divide - Shaping a Global Perspective on the Future of Work', 2024.
[130] Mennatullah Hendawy, 'The Intensified Digital Divide: Comprehending GenAI', Centre for Advanced Internet Studies (CAIS), 2024.
[131] Zhuo-Ya Du and Qian Wang, 'Digital Infrastructure and Innovation: Digital Divide or Digital Dividend?', *Journal of Innovation & Knowledge* 9, no. 3 (July 2024): 100542, https://doi.org/10.1016/j.jik.2024.100542.
[132] OECD, 'Digital Divides', 2024, https://www.oecd.org/en/topics/sub-issues/digital-divides.html.

5. Conclusion, takeaways, and future outlook

As border management continues to evolve in response to rapid technological advancements and changing global dynamics, it is clear that the integration of AI, biometrics, and other digital and modern technologies is redefining the landscape of national security and migration governance. These technologies present an unparalleled opportunity to improve border efficiency and security, particularly at the EU level, where major investments in technological infrastructure have strengthened border surveillance, identity verification, and data interoperability. However, their adoption also presents critical challenges related to ethics and fundamental rights. A key challenge for policymakers is to ensure that technological advancements are accompanied by and in line with robust legal frameworks, including secondary legislation and internal Standard Operating Procedures (SOPs), to guarantee accountability, ethical oversight, and compliance with international standards and international human rights. Without these in place, the risks and concerns regarding surveillance, discriminatory practices, and data security vulnerabilities are high. It is therefore important to balance between applying technological advancements and protecting individual rights.

Throughout this report, discussion on innovations in border management have highlighted both the benefits and the risks of these emerging technologies. These discussions were further reflected in recent dialogues among experts and policymakers, and actionable recommendations have emerged through the conferences which took place in Amman, Vienna, and Tunis over the course of 2024. With that, key takeaways and recommendations emerged and highlighted the importance of capacity building and training, ethical and legal frameworks, international collaboration and knowledge sharing, and technological integration and innovation.

Firstly, capacity building and training is considered essential to bridging the expertise gap in AI and equipping practitioners with the skills necessary to implement and operate new technologies effectively. Some of the suggestions highlighted by participants was the importance of awareness-raising workshops on the ethical use of AI, training sessions focused on identifying the risks, and the development of new tools. The need for structured training programmes, in collaboration with universities and civil society actors, was identified as a critical component of ensuring that border management professionals are equipped to operate and regulate these technologies effectively. Other innovative methods such as gamification and online courses could also make training accessible and more engaging. However, the challenge isn't just about delivering training, it is also about creating the right conditions for professionals to succeed. Many agencies lack specialised units or personnel skills in AI and other advanced systems. Closing this gap requires targeted capacity-building efforts and investment in the workforce and allows experts to operate these new technologies in a confident manner. However, training alone is insufficient; meaningful reform is necessary to align operational practices with emerging technologies, to ensure that they are integrated in a way that enhances both security and fundamental rights protections. Yet, as some experts have highlighted, modernisation is not achieved through digitisation alone. While integrating cutting-edge technologies is an important

step, true modernisation also requires reforming institutional structures, improving operational capacities, and ensuring that border agencies can effectively manage and adapt to these advancements. Without addressing these foundational issues, efforts toward digitalisation may fail to deliver their intended benefits.

Secondly, one of the strongest recurring themes in discussions around technological advancements in border management is the urgent need for clear ethical and legal guidance, based on already existing frameworks at the EU level at least. Modern border management cannot function effectively without a solid foundation of ethical and legal principles. Therefore, governments must prioritise the development and implementation of ethical and legal guidance that operationalise core ethical principles, ensure legal compliance, and address data governance concerns. The growing reliance on technologies, particularly AI, in border management highlights the need for standardisation of procedures to prevent risks such as bias, lack of transparency, and potential misuse. Acknowledging these risks calls for establishing mechanisms that ensure these tools are used in ways that align with international human rights standards. Beyond the overarching legal frameworks that are on an EU level, the development of internal Standard Operating Procedures (SOPs) across agencies are also important to ensure compliance (ensuring consistency, accountability, and alignment with fundamental rights) at the operation level as well. For example, for AI to serve as a reliable and equitable solution, governments must invest in frameworks that enhance transparency, accountability, and oversight. This could include the creation of a standardised code of conduct and a core ethical codebook that can be adapted to different regions and contexts. These measures are essential to addressing ethical concerns, such as data usage and potential biases, and mitigating risks, enhancing public trust, and making sure all technologies align with international human rights standards. The absence of harmonised regulatory approaches across the EU has led to fragmented implementation, increasing operational complexities and legal uncertainties. Even though the AI Act, Digital Services Act, and GDPR provide important regulatory benchmarks, gaps remain in ensuring consistent application, especially in regards to the opacity of AI-driven decision-making. This is why establishing clear operational procedures to protect human rights is important to prevent the misuse of these technologies.

Thirdly, international collaboration and knowledge sharing were highlighted as crucial factors to ensure the responsible implementation of technologies. These partnerships, not only among EU countries and institutions, but also with third countries and external agencies, are key to achieving standardisation of migration data systems and greater interoperability (where permissible). Fostering partnerships through agreements, organisations, and alliances to promote information sharing and infrastructure modernisation is considered a priority, also through a coordinated multi-country approach. Collaboration among various departments and agencies enables a more coordinated approach to tackle many of the key issues, including also transparency and addressing expertise gap. As noted in several discussions, partnerships with the private sector, international organisations, and local communities, should be reinforced as no single organisation or country can achieve success in isolation, especially when trying to bridge expertise gaps and promote a responsible approach to digital border governance. Hence,

partnerships and collaborations are considered a cornerstone of effective border management, as they foster trust, shared responsibility, and inclusive governance across all levels.

Fourthly, beyond the regulatory concerns, technological sustainability also remains an issue. The rapid deployment of digital border systems not only requires significant financial investment, but also long-term planning to ensure updates, protections and maintenance. Many of the delays in the rollout of major EU border control initiatives, such as the EES, highlighted the operational challenges of implementing such large-scale changes. Building on these considerations, technological integration and innovation remain the foundation of modern border management yet must be pursued with caution. While tools such as digital travel credentials and AI-powered platforms offer the potential to streamline processes and enhance efficiency, their successful implementation depends on addressing several operational challenges. These include budgetary constraints, especially in regards to the infrastructure needed to implement these technologies, the lack of specialised AI units, and the varying levels of digital maturity across regions – and this is crucial to overcome what has been identified as 'technological fear'. Additionally, it is also important to perform rigorous testing, maintenance, and the establishment of data centres to ensure reliability and accuracy of these technologies. Policy makers are encouraged to adopt advanced digital tools while also fostering public-private partnerships to drive research and development. To keep up with the rapid advancements, up to date regulations and comprehensive national strategies on digitisation and innovation are needed, otherwise their lack hampers the implementation of new technologies.

While these recommendations highlight pathways to modernising border management, it is important to stress again that modernisation does not mean technology alone. Deploying these new technologies without addressing the institutional, legal, and operational dimensions of border management risks creating fragmented and ineffective systems. As technologies continue to develop, they require a focus on building systems that integrate effectiveness with fairness and transparency, ensuring that all stakeholders, especially vulnerable groups, are considered in their deployment and use. Looking ahead, policymakers will need to remain adaptable, continuously refining legal frameworks and operational strategies to align with the rapid pace of technological change.

Contact Information

For more information please contact:

Christina Khoury and Maegan Hendow
Research Unit

International Centre for Migration Policy Development (ICMPD)

Rothschildplatz 4
1020 Vienna, Austria

Email: christina.khoury@icmpd.org; maegan.hendow@icmpd.org