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Crossing digital borders: technology in the migration process across the United States, Mexico, Honduras, and Chile

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This study examines the role of technology in migration processes across the United States, Mexico, Honduras, and Chile, with a focus on how technological tools are used primarily for control and management, and to a lesser extent, for facilitating integration. Through a qualitative methodology, including a comprehensive review of gray literature, this research analyzes the deployment of technologies by governmental and non-governmental institutions. Key findings reveal significant disparities in technological implementation, with the United States leading in advanced surveillance and control technologies, including biometric systems, artificial intelligence, and mobile applications like CBP One. In contrast, Mexico and Chile employ more limited technological tools, with Chile showing an emphasis on social inclusion through the Migrapp app. Honduras, on the other hand, lacks significant technological infrastructure for migration governance. The study highlights the risks associated with privacy invasion, surveillance, and social exclusion, particularly in the U.S, and calls for the responsible design and use of technology to ensure the protection of migrants' rights and to foster inclusion rather than exacerbate inequalities.

KEYWORDS

technology, migration, social inclusion, social technology, technological devices

1 Introduction

Migration movements are complex and multidimensional phenomena, influenced by various economic, political, social, and environmental factors (World Bank, 2022). Today, migration not only transcends geographical borders but also includes both national and transnational migration (Pripoaie et al., 2022), which has added to its complexity. This situation directly affects migrants' access to essential services such as healthcare and education, while also raising concerns about the protection of their human rights. Contemporary migration not only transforms the lives of those who migrate, but also reshapes the social dynamics of host societies.

Migrants are perceived in different ways: in some cases, they are seen as valuable contributors to economic and cultural diversity, while in others, they are perceived as a threat to social cohesion and national identity. Additionally, migration exacerbates pre-existing inequalities related to class, gender, ethnicity, and other social factors, redefining social categories and generating new meanings within the context of human mobility.

To understand the complexity of modern migration, it is essential to examine the power structures that underlie both individual and collective experiences in the migration context. As Foucault points out, power relations not only influence the creation of discourses and the formation of identities, but also operate through mechanisms of control and exclusion that regulate migration flows (Íñiguez Rueda, 2003; EDRi, 2024).

These dynamics manifest in the regulations, institutional practices, and devices of host societies, which can either promote the inclusion or exclusion of migrants, directly impacting public policy and social dynamics.

The COVID-19 pandemic has intensified many pre-existing crises, exacerbating food insecurity, violence, and environmental degradation, leading to an increase in forced migration (United Nations Development Programme, 2023). This context has highlighted the fragility of social and political systems, underscoring the urgent need to design effective policies to manage this forced migration. At the same time, the world is undergoing a profound technological and digital transformation, which presents both opportunities and challenges in the migration arena. Technological tools have emerged as "social technologies," designed and implemented to facilitate the inclusion of migrants, maintain connections between countries of origin and destination, and provide access to social services, labor information, and support networks. However, the use of these technological tools does not guarantee successful inclusion. While tools like mobile phones, the Internet, and applications like WhatsApp can mitigate isolation, they can also foster exclusion through criminalization, xenophobia, and the reinforcement of prejudices (Pérez Díaz and Aguilar Pérez, 2021; Cabalquinto, 2023).

Moreover, emerging technologies such as biometric devices and artificial intelligence algorithms are increasingly being used at migration borders, which has led to increased discrimination and exclusion based on "race" and other factors (United Nations High Commissioner for Human Rights, 2020). Therefore, it is crucial that technological tools used in migration processes are regularly reviewed to ensure their alignment with human rights, as highlighted by experts and international organizations (Gelb and Krishnan, 2018). However, significant gaps remain in understanding how these technologies affect migrants and host societies.

In this context, this research proposes a comprehensive review of the use of technological tools in migration processes in some countries of the Americas (the United States, Mexico, Honduras, and Chile), with a special emphasis on Latin America. The aim is to identify the strategies and technological devices used by governmental and non-governmental institutions to facilitate or regulate migration, and to analyze the potential benefits and risks these technologies pose to migrants.

This study also seeks to address the existing gaps in the scientific literature on the interaction between migration and technology, providing valuable information that could influence the development of fairer and more humane policies and technological tools. By examining the role of these tools, the study aims to contribute to rethink the design of migration technologies and policies that promote a more inclusive process respectful of human rights.

2 Methodology

This study was conducted using a qualitative methodology, employing a literature review process as the foundation for thematic analysis (Braun and Clarke, 2006). Qualitative research is a robust approach to explore complex phenomena and obtaining an in-depth understanding (Onwuegbuzie et al., 2012). Within this methodological framework, the literature review plays a crucial role in identifying, synthesizing, and evaluating a body of literature (Turyahikayo, 2014; Braun and Clarke, 2006). Subsequently, a thematic analysis was conducted to identify, analyze, and interpret recurring patterns or themes within the data set (Lochmiller, 2021).

2.1 Gray literature review process

Gray literature, including theses, news media archives, and technical reports, plays a pivotal role in research on technology. Its value stems from offering current information and unique perspectives that are often missing in traditional academic publications due to lengthy peer-review and publication timelines (Paez, 2017). The inclusion of gray literature is especially relevant in areas like security, where open sources may be limited, and in providing exclusive, recent data.

To harness the benefits of gray literature, a comprehensive review was conducted using Google as the primary search engine. Google was selected for its accessibility and widespread use in the countries analyzed, as it indexes diverse content, such as news, technical reports, government studies, and unpublished academic documents. Through Google, a wide range of updated and direct sources—often unavailable in traditional academic repositories—were accessed, including institutional publications, reports from international organizations, legislative documents, and news media. Google's ease of use and availability make it a key tool across multiple regions (StatCounter, 2024). An analysis by country shows that Google dominates in Chile, Mexico, the United States, and Honduras, with over 90% market share in each, reinforcing its role as the preferred platform for accessing information in these regions (StatCounter, 2024).

2.1.1 Keywords and search phrases

keywords: "technology and migration," "technological devices and migrants," "migration management systems," "migration surveillance," "Honduras, Mexico, Chile, United States".

Search Phrases in Spanish: "tecnología en migración Honduras OR México OR Chile OR Estados Unidos" "dispositivos tecnológicos y migración Honduras OR México OR Chile OR Estados Unidos" "sistemas de gestión de migración Honduras OR México OR Chile OR Estados Unidos" "vigilancia en migración Honduras OR México OR Chile OR Estados Unidos".

Search Phrases in English: "technology and migration Honduras OR Mexico OR Chile OR United States" "technological devices and migration Honduras OR Mexico OR Chile OR United States" "Migration management systems Honduras OR Mexico OR Chile OR United States" "migration surveillance Honduras OR Mexico OR Chile OR United States".

2.1.2 Inclusion criteria: document types and dates

The study includes news articles, technical reports, specialized blogs, and conference papers, emphasizing gray literature due to its timely and practical insights. These documents often cover real-world applications of technology in migration governance, offering perspectives crucial for the research's practical orientation. Documents published between 2019 and May 31, 2024, were included, reflecting rapid technological advancements in AI, big data, and digital platforms that have transformed migration governance. The COVID-19 pandemic and climate-induced migration have also driven the adoption of technologies for border control and migrant assistance during this period.

2.1.3 Inclusion criteria: countries of analysis

This study comprehensively explores the interplay between migration and technology, focusing on the United States, Mexico, Honduras, and Chile. These countries were chosen due to their distinct roles in migration dynamics and diverse technological landscapes shaped by unique economic, social, and political contexts. This selection allows for the examination of various American realities across different development levels.

The United States, as one of the most technologically advanced nations and the world's largest recipient of migrants, plays a critical role in shaping global migration dynamics. Despite its strong economy, marked by a high GDP and a culture of innovation, the country grapples with deep socioeconomic inequalities and political polarization, particularly around migration issues (International Monetary Fund (IMF), 2024). The U.S. employs cutting-edge technologies, including advanced surveillance systems, artificial intelligence, and data analysis, primarily at its southern border with Mexico to monitor migrants from the Northern Triangle countries (El Salvador, Honduras, and Guatemala) (Capps et al., 2017, 2019). These technologies significantly impact migrant routes, strategies, and decision-making processes. Moreover, organized crime and human trafficking continue to pose serious challenges within this migration landscape (Have et al., 2023). As the 2024 presidential elections approach, debates around immigration policy have intensified, focusing on how to balance national security with humane migration policies (AP News, 2024). These discussions reflect the broader socio-political landscape, where immigration remains a deeply divisive issue, influencing both domestic politics and international relations (AP News, 2024).

Mexico presents a complex scenario as both a major source of migrants to the U.S. and a keytransit country for Central and South American migrants (Basok and Candiz, 2020). Despite having one of the largest economies in Latin America, with the second-highest GDP in the region, high inequality, widespread poverty, and a significant informal sector drive many to migrate (Preker et al., 2021). Political instability and corruption exacerbate these challenges (Zepeda, 2014). Additionally, severe crime and violence, largely due to drug cartels, make migrants vulnerable to extortion, trafficking, and other dangers. While technology plays a crucial role in communication, risk management, and accessing information, the digital divide in Mexico limits its full potential (Coria and García-García, 2022a,b). These factors make Mexico a critical case for studying migration, technology, and socio-economic disparities.

In contrast, Honduras—predominantly a country of origin—faces high rates of emigration to the U.S. due to socioeconomic challenges and climate change, and it has one of the lowest GDPs in the region (World Bank, 2022; Have et al., 2023). Additionally, Honduras' strategic location in Central America has made it a critical transit route for migrants from countries like Venezuela, as well as a hotspot for organized crime and drug trafficking (UNOCHA, 2022). Technology is crucial for Honduran migrants to maintain family connections and send remittances. However, the country struggles with limited access to technology and poor digital literacy, which increases migrants' vulnerability to risks such as human trafficking (Organización Internacional para las Migraciones, 2023). These technological deficiencies hinder effective migration governance and human rights protection, limiting the potential for technology to safeguard migrants throughout their journeys.

Chile has emerged as a destination country, attracting migrants from neighboring nations due to its economic stability and steady growth over recent decades (United Nations Development Programme, 2023). With one of the highest GDP per capita in Latin America, strong export sectors, and a growing focus on technology and innovation, Chile presents an attractive destination for migrants seeking better opportunities (Marca Chile, 2022). However, Chile also faces sociopolitical challenges, such as increasing criminality, social polarization, and corruption (Solimano, 2012). The country's visa exemption policies for skilled migrants, investors, and certain nationalities facilitate migration but have also led to increased xenophobia and discrimination, particularly with the influx of Venezuelan immigrants. These issues are now central to public and governmental discourse (United Nations Development Programme, 2023). Chile's advanced technological infrastructure offers a unique environment to study how technology interacts with migratory processes, making it an important case for understanding the intersection between migration and technology.

2.1.4 Technologies included by the inclusion criteria

The research focuses on technologies aimed at adult migrants, without gender distinction, and implemented by governments and civil society. These technologies target different migration phases: preparation, the migratory act, settlement, and integration (Tizón et al., 1992). They are examined for their impact on enhancing migrants' experiences and outcomes.

2.1.5 Exclusion criteria

The study excluded documents that were incomplete, inaccessible, or behind paywalls, as well as scientific articles and books. The focus is on gray literature to capture practical insights into migration technology, which are often more immediate than those found in academic publications. Additionally, documents that centered on migration governance through social networks or informal surveillance platforms were excluded, to maintain a specific focus on formal technological interventions implemented

by governments and civil society. Furthermore, technologies designed for and implemented with minors were excluded from the study. This decision was made based on ethical considerations and human rights principles, as these technologies should only be applied to adults with informed consent (United Nations Population Fund (UNFPA), 2023).

2.2 Document selection process

During the initial review of titles, researchers identified 1,255 documents retrieved from the search. The document selection process began with three researchers conducting the initial search together, which yielded a total of 1,255 documents. From this pool, the researchers collaboratively reviewed and preselected, based on title, abstract, and consensus regarding the relevance to the research objectives and the inclusion and exclusion criteria. After this collective revision, a total of 110 documents based were preselected. To ensure the quality of the final selected documentation, the three researchers independently reviewed the abstract of each pre-selected document (110 documents). The following criteria guided their individual and evaluation:

- Clarity and precision of information: Reviewers assessed whether the information presented was clear, concise, and accurate.
- Relevance and applicability to the research: Reviewers analyzed whether the document's content was pertinent and applicable to the research objectives.

Following individual reviews, the researchers identified documents that were unanimously included or excluded. Any discrepancies in document selection were resolved through discussion and consensus among the reviewers. This process fostered a dialogue that facilitated well-reasoned and collaborative decision-making, having in mind the objectives, inclusion and exclusion criteria. See Figure 1 to obsere the dcument selection process.

2.2.1 Quality of the selected sources

Finally, and related to the quality of the gray literature sources, used in this research on migration and technology reveals a notable diversity of origins, each with varying levels of quality and credibility (see Table 1), which is crucial for constructing a solid and

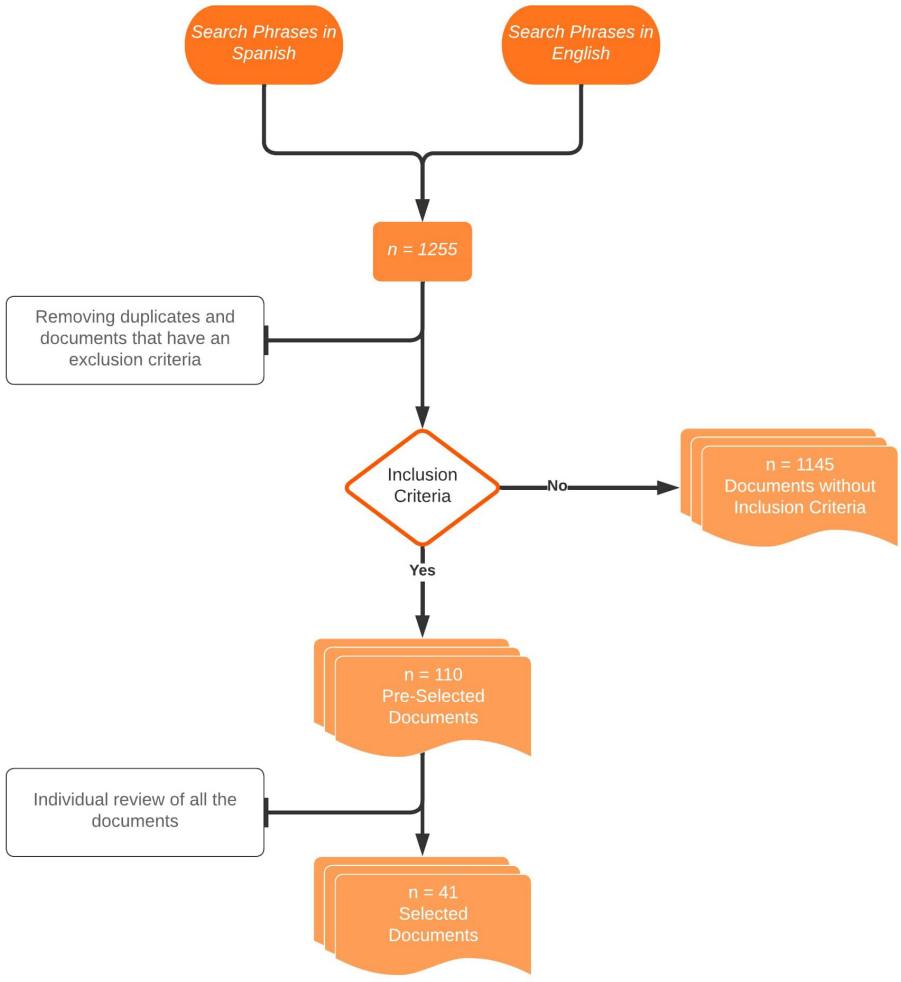

FIGURE 1
Flowchart of the document selection processed.

multifaceted academic study. Government sources, such as the U.S. Department of Homeland Security, and international organizations like UNHCR, provide essential official data. For understanding this situation. On the other hand, non- governmental organizations such as Amnesty International and Human Rights Watch offer critical perspectives rooted in human rights, based on independent research. Prestigious media outlets, like the BBC, AP NEWS, and The Guardian, provide up-to-date information, though it is important to consider potential editorial biases in some of these types of sources. Think tanks, such as CSIS, deliver in-depth analyses of the implications of migration technologies, which should be complemented by other viewpoints. Finally, specialized blogs, while less formal, can capture emerging voices but require critical evaluation of their quality. Quantitatively, media outlets constitute 33.3% of the total sources, followed by government sources (26.7%), NGOs (16.7%), think tanks (13.3%), and blogs (10%). This distribution reflects a multidimensional approach, with a strong emphasis on journalistic and governmental sources, complemented by critical analyses from NGOs and think tanks.

2.3 Data extraction and synthesis

The data extraction and synthesis process was carried out meticulously, focusing on four key areas that align with the objectives of this research: (a) types of technologies used, (b) countries of implementation, (c) types of organizations employing them, and (d) adopted migration strategies. The synthesis of the main findings from each document is included in a summary Table 1, which provides a clear overview of the relevant insights gathered from the selected sources.

3 Analysis procedure

To identify trends, categories and broader themes of analysis, a process for conducting thematic analysis of the literature was carried out (Lochmiller, 2021).

3.1 Reading and familiarization with the data

Initially, the three researchers thoroughly read the 41 selected documents with the aim of understanding the overall content and the topics covered. During this preliminary reading, detailed notes were taken, highlighting key ideas and themes that appeared recurrently in the texts.

3.2 Coding of relevant information

At this stage, significant words, phrases, and ideas that were important or frequently mentioned in the documents were identified. These units of meaning were highlighted and assigned labels or "codes" that summarized their essential content. This process allowed for systematic organization of the information and facilitated the identification of central concepts.

3.3 Grouping of codes into categories

Subsequently, the codes were analyzed to find similarities and relationships between them. Codes that were related or similar were grouped into broader categories that represented general concepts. For example, codes such as "drones" and "surveillance cameras" were integrated under the category of Surveillance Technologies. Likewise, to create larger thematic groupings, frequency observations were made, indicating relevant themes.

4 Results

Following the extraction and synthesis procedure, the information was analyzed based on the identification of patterns and trends.

4.1 Emerging categories

The emerging categories identified were the following:

- Technological Devices for Detection and Identification of Migrants
- Technological Devices for Obstruction of Migrants
- Artificial Intelligence
- Mobile Applications for Surveillance and Management of Migrants
- Mobile Applications for Social Inclusion of Migrants.

4.2 Identified patterns

4.2.1 Themes

Concerning the data analysis, a detailed evaluation of various technologies used for migration surveillance and management was conducted. The following themes emerged:

1. Technologies and Strategies for Control, Management, and Surveillance by Governments.
2. Technologies for Social Inclusion by Non-Governmental Organizations.

1. Description Theme 1: Technologies and Strategies for Control, Management, and Surveillance by Governments.

- Technologies and Strategies for Control, Management, and Surveillance by Governments: Currently, nations are investing in digital borders capable of detecting people, vehicles, and animals along their boundaries, as well as employing devices for facial recognition and location tracking of migrants (Mijente, 2021). Specifically, the United States has implemented a sophisticated technological infrastructure to control immigration at its borders. This infrastructure

TABLE 1 Selected documents.

No.	Link	Publication Date	Title	Source	Type of Document	Findings
1.	https://www.swissinfo.ch/spa/migrantes-y-tecnolog%C3%ADa-c%C3%B3mo-los-m%C3%B3viles-cambian-la-ruta-~hacia-estados-unidos/48299154	February 19, 2023	Migrants and technology: how mobile phones are changing the path to the United States	Swiss Info	News	• Technology: CBP • Type of use: Governmental • Country of use: USA • Implemented for: accelerating asylum application processes.
2	https://www.bbc.com/mundo/noticias-47198526	February, 12, 2019	Trump and the wall: what the technology looks like at the border fence between Mexico and the United States	BCC NEWS	News	• Technology: Integrated Fixed Towers (IFT), longer range cameras and radars, Sensors, mobile surveillance trucks, night vision goggles • Type of use: Government • Country of use: USA • Implemented to: detect, identify, and locate those who try to cross illegally.
3	https://idehpucp.pucp.edu.pe/boletin-eventos/muros-digitales-las-implicaciones-de-las-nuevas-tecnologias-digitales-en-~fronteras-28252/	May 30, 2023	"Digital walls" the implications of new digital technologies on borders	The Institute of Democracy and Human Rights (Idehpucp) is an academic unit of the Pontifical Catholic University of Peru	Bulletin	• Technology: ground sensors, identification systems, video drones, facial recognition, artificial intelligence, surveillance towers, biometric technology, CBP One • Type of use: Government • Country of use: USA • Implemented to: identify and locate suspicious activities on the ground, border guarding through continuous aerial surveillance, streamline detention and deportation processes, decision-making in the visa process, and improve the border security, prevention, and surveillance at the border. The use of the towers is correlated with an increase in migrant deaths, analyze and process physiological characteristics such as footprints, irises, and facial features, use geolocation and facial recognition data to recognize, track, and save applicant data from their arrival at the border. According to the U.S. government, it is implemented to improve the efficiency of the CBP system.
4	https://www.latimes.com/espanol/eeuu/articulo/2024-03-14/eeuu-requiere-que-migrantes-sin-pasaporte-se-sometan-a-reconocimiento-facial-para-abordar-vuelos	14, 2024	U.S. requires migrants without passports to undergo facial recognition to board flights	Los Angeles Times	News	• Technology: facial recognition • Type of use: Government • Country of use: USA • Implemented for: identity verification for Department of Security files.
5	https://www.acnur.org/noticias/historias/chile-migrapp-la-joya-del-sjm-que-conecta-tecnologia-y-solidaridad-celebra-dos	Aug 13–21	Chile: Migrapp, the jewel of the SJM that connects technology and solidarity, celebrates 2 years of operation	UNHCR		• Technology: Migrapp • Type of use: Non-governmental (Jesuit migrant service SJM and funded by UNHCR) • Country of use: Chile • Implemented to: promote social inclusion and access to rights of refugees and migrants in Chile. It has managed to amplify the delivery of guidance at different moments of the migrant process and in the delivery of a response that understands refugees and migrants as subjects of rights and with active listening beyond virtuality.

(Continued)

TABLE 1 (Continued)

No.	Link	Publication Date	Title	Source	Type of Document	Findings
6	https://www.elsaltodiario.com/migracion/tecnologias-se-usan-para-vigilar-personas-migrantes-despues-se-usan-resto-poblacion	10-Jun-22	Cinthya Rodriguez: "The technologies that are used to monitor migrants are then used with the rest of the population"	The Daily Leap	News	• Technology: electronic shackles, smart link app, drones, security cameras and motion sensors • Type of use: Government • Country of use: USA • Implemented to: locate people in real-time, record voice, and communicate, the Smart Link app allows ICE officers to permanently follow the steps of migrants, who must report frequently (weekly, daily, even several times a day) and send selfies, Monitor, and control everything that happens at the border, contain the entry of undocumented immigrants. The sensors identify movement and have been placed to cover the stretch of the border.
7	https://www.eltiempo.com/mundo/eeuu-y-canada/esta-es-la-tecnologia-que-usa-cbp-para-detectar-a-los-indocumentados-en-una-zona-3326426	20.03.2024	This is the technology CBP uses to	Weather	News	• Technology: security cameras, motion sensors • Type of use: Government • Country of use: USA • Implemented for: monitoring, and sending agents if necessary, to the most inhospitable corners
8	https://www.telemundo.com/noticias/noticias-telemundo/hispanos-en-ee-uu/muro-fronterizo-tecnologia-inteligencia-artificial-rcna129274	December 12, 2023	Technology for a digital wall: how artificial intelligence and video surveillance are used on the border	Telemundo	News	• Technology: surveillance towers, Artificial Intelligence for vehicle scanning, robot dogs, license plate readers, facial recognition • Type of use: Government • Country of use: USA • Implemented for: scanning several kilometers at a distance and scanning private and cargo vehicles when crossing the border (the creation of this technology was requested), Patrol the border, Video surveillance.
9	https://www.youtube.com/watch?v$=$cATMumgHwoI	March 30, 2024	Technology for a digital wall: how artificial intelligence and video surveillance are used on the border	Milenial Digital	News	• Technology: electronic shackles Type of use: Government • Country of use: USA • Implemented to: monitor migrants who are within their territory waiting for a court date while they regulate their immigration status
10	https://www.state.gov/translations/spanish/hoja-informativa-el-gobierno-de-ee-uu-anuncia-nuevas-medidas-energicas-para-gestionar-la-migracion-regional/	April 27, 2023	Fact Sheet: U.S. Government Announces New Crackdown to Manage Regional Migration	The U.S. Government	Fact Sheet	• Technology: CBP One • Type of use: Government • Country of use: USA • Implemented for: request asylum appointments
11	https://www.es.amnesty.org/en-que-estamos/reportajes/derechos-personas-refugiadas-y-migrantes-en-la-era-digital/	March 15, 2024	Migrants' rights in the digital age	Amnesty International	Report	• Technology: CBP one, electronic tracking devices, facial and voice recognition applications, radars, high-tech cameras and drones, artificial intelligence powered surveillance towers, biometrics • Type of use: Government • Country of use: USA • Implemented to: schedule an appointment and present yourself at a port of entry, instead of attempting to enter areas located between such ports, controlling migrants and asylum seekers outside the prison

(Continued)

TABLE 1 (Continued)

No.	Link	Publication Date	Title	Source	Type of Document	Findings
						environment. Examples include the Intensive Supervision Appearance Program (ISAP) and the Border Monitoring, Surveillance, and Monitoring Devices Program, Identification, Verification, and Authentication of Persons at the Border
12	https://www.state.gov/translations/spanish/ficha-informativa-cbp-one-facilito-mas-de-170-000-citas-en-seis-meses-y-continua-siendo-una-herramienta-segura-ordenada-y-humana-para-la-~gestion-de-fronteras/	August 3, 2023	Factsheet: CBP One facilitated more than 170,000 appointments in 6 months and continues to be a safe, orderly, and humane tool for border management	U.S. Department of State	Press Release	• Technology: CBP One • Type of use: Government • Country of use: USA • Implemented for: scheduling an appointment and presenting yourself at a port of entry, rather than attempting to enter areas located between those ports
13	https://www.france24.com/es/am%C3%A9rica-latina/20230329-un-mejor-tel%C3%A9fono-para-sortear-los-fallos-de-la-app-cbp-one-as%C3%AD-es-la-lucha-por-lograr-asilo-en-ee-uu	29/3/2023	A better phone to get around the failures of the CBP One app, this is the fight to achieve asylum in the US	France 24	News	• Technology: CBP One • Type of use: Government • Country of use: USA • Implemented for: scheduling an appointment and presenting yourself at a port of entry, rather than attempting to enter areas located between those ports
14	https://www.hrw.org/es/news/2024/05/01/ee-uu-el-mecanismo-de-entrada-digital-cbp-one-expone-migrantes-danos	May 1, 2024	U.S.: "CBP One" Digital Entry Mechanism Exposes Migrants to Harm	Human Rights Watch	New	• Technology: CBP One • Type of use: Government • Country of use: USA • Implemented to: schedule an appointment and report to a port of entry, rather than attempting to enter areas located between those ports
15	https://www.interior.gob.cl/noticias/2021/09/30/gobierno-anuncia-medidas-para-enfrentar-la-migracion-en-la-zona-norte/	September 30, 2021	Government announces measures to tackle migration in the northern zone	Ministry of the Interior and Public Security, Government of Chile	Press Release	• Technology: trucks with satellite antennas • Type of use: Government • Country of use: Chile • Implemented for: monitoring to reinforce the surveillance of migrants in the northern part of the country.
16	https://www.vozdeamerica.com/a/dificultades-enfrentan-migrantes-cbp-one-/6924643.html	January 19, 2023	What difficulties do migrants face with the CBP One app?	Voice of America	News	• Technology: CBP One • Type of use: Government • Country of use: USA • Implemented to: schedule an appointment and present yourself at a port of entry, instead of attempting to enter areas located between those ports
17	https://cnnespanol.cnn.com/video/ice-telefonos-rastreo-migrantes-perspectivas-buenos-aires/	June 6, 2022	ICE uses cellphones without internet to track migrants	CNN en Spanish	News	• Technology: Smartlink App • Type of use: Government • Country of use: USA • Implemented for: tracks via phones
18	https://www.lanacion.com.ar/el-mundo/tension-en-la-frontera-entre-mexico-y-eeuu-sensores-de-calor-drones-black-hawk-y-hasta-perros-robot-nid11052023/	May 12, 2023	Tension on the border between Mexico and the U.S.: heat sensors, drones, Black Hawk and even "robot dogs" to stop the crossing of migrants	La Nación	News	• Technology: robot dogs, drones and heat sensors • Type of use: Government • Country of use: USA • Implemented for: tracking and monitoring migrants

(Continued)

TABLE 1 (Continued)

No.	Link	Publication Date	Title	Source	Type of Document	Findings
19	https://www.elheraldo.hn/elheraldoplus/investigaciones/hondurenos-migracion-estados-unidos-monitoreo-grilletes-gps-KB13745168	June 3, 2023	Honduran migrants, among the most monitored by the United States	The Herald	News	• Technology: electronic shackles • Type of use: Government • Country of use: USA • Implemented to: prevent migrants from waiting in prison for a judicial resolution of their immigration status
20	https://hias.org/es/noticias/app-CBP-one-grandes-desafios/	November 8, 2023	For Asylum Seekers, the CBP One App Poses Major Challenges	Hebrew Society for Immigrant Aid (HIAS)	News	• Technology: CBP One • Type of use: Government • Country of use: USA • Implemented for: Request an appointment
21	https://www.bbc.com/mundo/noticias-internacional-65539740	May 11, 2023	End of Title 42: the new measures that tighten control over migrants arriving at the U.S. border	BBC News	News	• Technology: CBP One • Type of use: Government • Country of use: USA • Implemented to: request an appointment
22	https://www.tni.org/es/art%C3%ADculo/la-frontera-omnipresente	November 24, 2023	The omnipresent border, the digital infrastructure of migration control in the Americas	Transnational Institute	Specialized Blog	• Technology: robot dogs, biometric collection devices • Type of use: Government • Country of use: USA • Implemented for: Border surveillance
23	https://calmatters.org/calmatters-en-espanol/2024/01/la-patrulla-fronteriza-instalara-casi-300-torres-de-vigilancia-adicionales-en-la-frontera-entre-~mexico-y-california/	January 30, 2024	Border patrol to install nearly 300 additional watchtowers on Mexico-California border	Call matters	News	• Technology: watchtowers, artificial intelligence • Type of use: Government • Country of use: USA • Implemented to: autonomously identify and track "objects of interest", such as humans or vehicles
24	https://buslahr.medium.com/the-use-of-technology-at-an-increasingly-busy-u-s-mexico-border-66c41cd01a2c	April 12, 2024	The Use of Technology at an Increasingly Busy U.S.-Mexico Border	Medium	News	• Technology: CBP One • Type of use: Government • Country of use: USA • Implemented for: scheduling an appointment and presenting yourself at a port of entry, rather than attempting to enter areas located between those ports
25	https://www.dhs.gov/sites/default/files/publications/2011005-hoja-informativa-immigracion.pdf	May 22, 2022	Sensible and effective border security and immigration control	U.S. Department of Homeland Security	Press Release	• Technology: inspection systems, mobile surveillance systems, video systems for remote surveillance, thermal detection systems, radiation detection portals, and driver's license readers • Type of use: Government • Country of use: USA • Implemented for: border surveillance and illegal entry of migrants
26	https://features.csis.org/Tracked-Migration-Technology-and-Human-Rights/	December 15, 2022	Tracked: stories at the intersection of migration, technology, and human rights	Center for Strategic & International Studies	Specialized Blog	• Technology: drones, night vision goggles, biometric systems • Type of Use: Government • Country of Use: USA, Mexico • Implemented for: managing who arrives or passes through your countries
27	https://www.amnesty.org/en/latest/news/2024/02/global-amnesty-international-publishes-an-introduction-to-defending-the-rights-of-refugees-and-migrants-in-the-digital-age/	February 5, 2024	Global: Amnesty International publishes an introduction to defending the rights of refugees and migrants in the digital age	Amnesty International	News	• Technology: Intensive Appearance Monitoring Program and Electronic Device Surveillance Program • Type of use: Government Country of use: USA • Implemented for: monitoring migrants and asylum seekers released from detention

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TABLE 1 (Continued)

No.	Link	Publication Date	Title	Source	Type of Document	Findings
28	https://cl.usembassy.gov/fact-sheet-third-ministerial-meeting-on-the-los-angeles-declaration-on-migration-and-protection-in-guatemala/	May 7, 2024	Fact Sheet: Third Ministerial Meeting on the Los Angeles declaration on migration and protection in guatemala	U.S. Embassy in Chile	Press Release	• Technology: CBP One • Type of use: Government • Country of use: USA • Implemented to: request an appointment
29	https://www.migrationpolicy.org/sites/default/files/publications/mpi-contemporary-border-policy-2024_final.pdf	January 2024	Shifting Realities at the U.S.-Mexico Border	U.S. Immigration Policy Program	Technical Report	• Technology: CBP One • Type of use: Government • Country of use: USA • Implemented for: request Asylum Appointments
30	https://www.jrsusa.org/wp-content/uploads/sites/2/2024/04/Final_JRS_2024_Policy-Brief_Navigating-U.S.-Mexico-Border-JU2.pdf	April 17, 2024	Navigating the U.S. - Mexico Border - Digital Practices of Migrants and Their Psychosocial Needs	Jesuit Refugee Service-USA	Technical Report	• Technology: CBP One • Type of use: Government • Country of use: USA • Implemented to: request an appointment
31	https://www.amnestyusa.org/reports/the-digital-border-migration-technology-and-inequality/	May 21, 2024	The digital border: migration, technology and inequality	Amnesty International	Technical Report	• Technology: Military-grade surveillance and deterrence technologies, including a network of security towers equipped with cameras, heat sensors, motion sensors, and other so-called "smart" border technologies, Advanced Homeland Reconnaissance Technology System (HART). • Type of use: Government • Country of use: USA • Implemented for: border surveillance and illegal entry of migrants
32	https://www.amnesty.org/en/latest/news/2024/05/global-new-technology-and-ai-used-at-borders-increases-inequalities-and-undermines-human-rights-of-migrants/	May 21, 2024	Global: New technology and AI used at borders increases inequalities and undermines human rights of migrants	Amnesty International	News extracted from the technical report "The digital frontier: migration, technology and inequality"	• Technology: biometric sensors, drone surveillance, CPB One • Type of use: Government Country of use: USA • Implemented for: border surveillance and illegal entry of migrants
33	https://www.csis.org/analysis/expanding-use-technology-manage-migration	March 6, 2023	The expanding use of technology to manage migration	CSIS Center for strategic international studies	Technical Report	• Technology: drones, cell phone data, geolocation data, digital travel documents, aerial imagery • Type of use: Government • Country of use: USA • Implemented for: migrant location
34	https://www.ohchr.org/en/video/2023/digital-technologies-and-migration	Sep 18, 2023	Digital technologies and migration	United Nations	News	• Technology: biometric data, automated visa applications, emotion detection system, drones • Type of use: Government • Country of use: USA • Implemented for: location of migrants
35	https://apnews.com/article/technology-united-states-government-caribbean-mexico-mobile-apps-49b38b18869ed3b2260fb6d774153456	January 28, 2023	Online system to seek asylum in US is quickly overwhelmed	Apnews	News	• Technology: CBP One • Type of use: Government • Country of use: USA • Implemented for: request Asylum Appointments

(Continued)

TABLE 1 (Continued)

No.	Link	Publication Date	Title	Source	Type of Document	Findings
36	https://www.wired.com/story/help-migrants-border-aid-groups-deploy-tech/	Aug 11, 2019	To help migrants at the border, aid groups deploy tech	Wired	News	• Technology: digital locker, storage tool from Innovation Law Lab, Mobile technology with a WhatsApp and Facebook messaging program • Type of use: Non-governmental • Country of use: USA • Implemented for: helping immigrants and human rights defenders, Offers health advice (how to avoid dehydration or cholera, for example) and maps that guide migrants to shelters used by The International Committee on Human Rights (ICRC). Red Cross (ICRC)
37	https://www.latimes.com/business/story/2023-05-17/how-tiktok-and-other-social-media-changed-the-way-people-migrate-to-the-u-s-in-the-title-42-era	May 17, 2023	"Their only lifeline" for migrants at the U.S. border: smartphones and TikTok	Los Angeles Time	Blog	• Technology: use of TikTok, Facebook, YouTube, and other social media sites, CBP One • Type of use: Non-Government • Country of use: USA • Implemented to: share updates about the policy change and how it might affect them; Make an appointment and report to a port of entry, rather than attempting to enter areas between those ports
38	https://www.cbp.gov/newsroom/national-media-release/cbp-releases-january-2024-monthly-update	02/13/2024	CBP Releases January 2024 Monthly Update	US Customs and border protection	Press release	• Technology: CBP One; The Global Entry mobile app and mobile passport control, as well as the new Global Entry contactless portals • Type of use: Government • Country of use: USA • Implemented for: scheduling an appointment and reporting to a port of entry, rather than attempting to enter areas located between those ports; Protect passenger privacy and streamline arrival processing by eliminating paper receipts
39	https://bipartisanpolicy.org/download/?file$=$/wp-content/uploads/2021/05/Immigration-Border-SecurityV3.pdf	May-21	Redefining border security	Bipartisan Policy Center's	Technical Report	• Technology: tunnel detection as a border • Type of use: Government • Country of use: USA • Implemented for: cybersecurity protection, tunnel detection technology. as a border increase in fences and infrastructures, use of tunnels
40	https://www.theguardian.com/us-news/2024/feb/06/us-immigration-bill-mexico-border-surveillance-privacy	Tue 6 Feb 2024	A privacy nightmare': the $400 m surveillance package inside the US immigration bill	The Guardian	News	• Technology: sensors, on-board computing and artificial intelligence, mobile video surveillance systems and drones, automated surveillance towers, autonomous towers Anduril • Type of use: Government • Country of use: USA • Implemented to: protect the privacy of the people to identify items of interest and control migration
41	https://www.hrw.org/news/2024/05/01/us-digital-metering-system-exposes-migrants-harm	May 1, 2024	US: digital metering system exposes migrants to harm	Human Rights Watch	Press release based on a report	• Technology: CBP One • Type of use: Government • Country of use: USA • Implemented to: schedule an appointment and report to a port of entry, rather than attempting to enter areas located between those ports, to limit the number of asylum seekers processed at ports of entry each day, and to return others to Mexico.

includes high-tech surveillance systems such as fixed towers equipped with cameras and radar, motion sensors, mobile surveillance trucks, and drones. In addition, the U.S. utilizes biometric technologies and communication interception tools to identify, track, and monitor migrants. In Mexico, some of these technologies have also been adopted, though their implementation is less extensive compared to the United States. In Chile, satellite antenna-equipped trucks are used for monitoring and surveillance of migrants in the northern region of the country.

- Technological Devices for Obstructing People: In the United States, the Digital Border Wall represents a technological barrier integrating multiple devices to prevent the passage of individuals, while considering that data tracking poses a risk for asylum seekers, as this information could be used against them due to a lack of transparency in the registration and storage of private data (Witteborn, 2022). This system combines cameras, sensors, and other advanced technologies to create a robust defense, evolving traditional border control strategies into a more effective and technological integration.
- Artificial Intelligence: The use of AI at borders presents many ethical and moral challenges, as it can reinforce stereotypes and oversimplify the complex causes of discrimination, perpetuating social inequalities (Jiménez Quiñones, 2023). The United States also employs a variety of independent technologies for immigration management. Artificial intelligence plays a crucial role in analyzing large datasets, which allows for the identification of migration patterns, assessment of potential risks, and improved efficiency in border surveillance. This data analysis, combined with other surveillance technologies, provides authorities with an unprecedented ability to track and monitor migration flows.
- Mobile Applications for Surveillance and Management: In the United States, mobile applications play a crucial role in migration surveillance and management. The CBP ONE app is used to schedule appointments and present migrants at ports of entry, as well as for facial recognition and geolocation. The Smart Link app allows ICE officers to continuously monitor the movements of migrants, who must frequently check in and send selfies to confirm their location. These government-implemented applications for migration management have become facilitators of social classification, assessing risks associated with migrant entry (Leese et al., 2022). Additionally, automated visa applications streamline visa processes through automated technologies.

2. Description Theme 2: Technologies for Social Inclusion by Non-governmental Organizations.

According to the review data the only technology designed for social inclusion is the chilean Migrapp app, developed by the Jesuit Migrant Service and funded by UNHCR, facilitates social inclusion and access to rights for migrants and refugees. It provides guidance and essential resources, supporting migrants in their integration into society. This app, developed by the Jesuit Migrant Service and funded by UNHCR, serves as a tool for promoting social inclusion and that migrants and refugees have access to essential rights and services. It provides information on documentation, legal processes, public services, and community resources, helping migrants navigate local systems and overcome potential barriers to integration. It also offers guidance on cultural adaptation and employment searches, along with real-time support from advisors and migration experts. Through its community-building features, such as forums and discussion groups, Migrapp helps migrants establish support networks, enhancing both their social and emotional integration. Migrapp's comprehensive approach supports migrants throughout the entire migration process, from pre-move preparations, where it offers information on visa requirements and necessary documentation, to post-arrival integration, where it facilitates access to healthcare, education, and other essential services. Additionally, the app provides ongoing assistance for navigating cultural and labor market challenges, while helping users maintain their legal status (Servicio Jesuita a Migrantes, 2024).

4.3 Identified patterns

The results identified the following patterns in the use of technology for migration governance across the countries studied, which communicated that the results in this paper are aligned to previous generated data.

- Extensive Use of Advanced Technologies in the United States: The deployment of fixed towers, drones, cameras, and sensors demonstrates a comprehensive and sophisticated approach to migration surveillance and control in the U.S. This reflects the country's strong investment in emerging technologies for border management (Mijente, 2021; Jiménez Quiñones, 2023; Witteborn, 2022).
- Limited Use of Technologies in Mexico and Chile: While both countries utilize emerging technologies, their implementation is considerably less extensive than in the United States. The technological tools used in migration governance are not as widespread or integrated into broader systems of surveillance and control (Center for Strategic International Studies, 2024; Mixed Migration Centre, 2024).
- Minimal Use of Technologies in Honduras: Unlike the U.S., Mexico, and Chile, Honduras presents a different landscape in terms of migration technology. Despite facing similar migration challenges to countries like Mexico, there is little evidence of significant use of emerging technologies for migrant detection, integration, identification, or management (International Organization for Migration, 2021; Amnesty International, 2024).
- Mobile Applications for Social Inclusion: There was only one case of a mobile application Migrapp, developed in Chile specifically for the social inclusion of migrants. This application plays an essential role in supporting migrants, demonstrating the potential of technology to ethically facilitate migration and social inclusion (Servicio Jesuita Migrante, 2024).

TABLE 2 Emerging categories and broader themes.

Initial areas	Emerging categories	Themes
Type of technologies Used	Technological devices with integration for detection and identification of migrants	Technologies and strategies for control, management, and surveillance by governments
Countries of implementation	Technological devices for obstruction of migrants	
Type of organization employing the technology	Artificial intelligence	Technology for social inclusion by non-governmental organizations

4.4 Analysis of technology in the phases of the migration process

To further analyze the results concerning the use of technology in the stages of migration, we have decided to adopt the framework proposed by Tizón et al. (1992). This model identifies four key stages of the migration process: preparation, the migratory act, settlement, and integration. By using this framework, we were able to systematically examine the role of technology at each phase of migration.

According to the analysis of the 41 documents, technologies focused on detecting and identifying migrants are used during the preparation phase, allowing them to plan their journey. An example of this is the use of biometric devices and surveillance cameras at borders to anticipate risks and identify the safest routes.

Additionally, during this phase, automated visa management applications are highlighted, making it easier for migrants to obtain the necessary documents before starting their journey. During the migration phase, which features the largest number of identified technologies, tools such as obstruction devices, like the Digital Border Wall in the United States, combine sensors and cameras to prevent unauthorized crossings. Mobile applications like CBP One are also used to manage appointments and monitor migrants throughout their journey, while artificial intelligence assists authorities in analyzing migration flows and predicting risks.

In the settlement phase, technologies shift their focus toward facilitating the adaptation of migrants in destination countries. Applications like Migrapp in Chile provide key information about healthcare, education, and employment services, helping migrants integrate into society.

Finally, in the integration phase, Migrapp continues to support the social and cultural inclusion of migrants, offering guidance on the labor market, legal processes, and promoting the formation of community networks that facilitate their complete integration into the host society.

4.5 Analysis of technologies in migration governance

The analysis of the 41 documents in Table 2 reveals that most technologies in the migration domain are geared toward the control, surveillance, and management of migrants, particularly during the migration phase. Technologies like detection and identification devices, the Digital Border Wall in the United States, and mobile applications like CBP One and SmartLink play a crucial role in monitoring and regulating migration flows.

These tools, along with the use of artificial intelligence, enable authorities to anticipate risks, track migrants, and manage their entry. However, in the preparation phase, technologies that facilitate visa management also stand out, streamlining the process of obtaining documents before migrants embark on their journey. Although the primary focus of these technologies is control, some, such as visa management applications and tools that facilitate the regularization of immigration status, indirectly contribute to the integration of migrants by reducing bureaucratic barriers. Additionally, technologies designed for social inclusion, such as the Migrapp application in Chile, provide access to essential services like healthcare, education, and employment, supporting migrants in adapting to the host society. This shows that, despite the predominance of control, certain technological elements can facilitate the integration and settlement of migrants in their new environments.

Similarly, some technologies designed for control, such as automated visa processes, although primarily intended for managing migration flows, can speed up the documentation needed for labor insertion or enrollment in social services, which are key elements of integration. In these cases, while the technology was not specifically created with a social inclusion focus, its implementation can have positive effects on integration by reducing the bureaucratic barriers migrants face when settling and fully participating in the host society. Therefore, even though the main focus of many technologies is control, certain elements in their design can facilitate key aspects of integration, such as the legalization of immigration status, which in turn opens doors to other essential services.

4.6 Analysis of the potential and risks of technologies

Migration management stands at a crossroads where emerging technologies offer both potential benefits and significant risks. On one hand, the use of technology-integrated devices for the detection and identification of migrants promises greater efficiency in border management. These technologies allow for the monitoring of vast areas, identification of potential illegal crossings, and expedited processing of individuals. Similarly, the creation of "smart borders" offers increased control over migration flows through strategic obstruction. Furthermore, surveillance technologies can be valuable tools in combating transnational crimes, such as human trafficking, drug smuggling, and arms trafficking, by providing real-time information on suspicious activities (Feldstein, 2024).

However, this technological approach to migration is not without its risks. The mass collection and storage of biometric data,

geolocation information, and the use of social media surveillance could pose a serious threat to privacy and human rights (Klauser, 2018). The use of algorithms and artificial intelligence in migration governance raises concerns about perpetuating existing biases and leading to discrimination based on origin, race, or religion. Concerns may also arise regarding the ethical dilemmas posed by the implementation of AI, particularly concerning marginalized populations (Cabrera et al., 2023; Dauvergne, 2020).

Another risk associated with the use of technologies in migration processes is the lack of transparency and accountability. The opacity surrounding the use of these technologies and the lack of access to information about how data is collected, stored, and used opens the door to potential abuse. Finally, intrusive surveillance can create a climate of fear and intimidation, deterring not only migrants but also civilians from accessing essential services and exercising their fundamental rights (Molnár, 2023; ReliefWeb, 2023; International Organization for Migration, 2023).

The results of the study on the use (or lack of use) of technology in migration across the United States, Mexico, Honduras, and Chile largely align with the theoretical framework and methodological expectations outlined in the introduction and methodology sections. Specifically, the extensive use of emerging technologies in the United States—such as fixed towers, drones, cameras, and sensors—reflects the country's well-established technological landscape for migration control, as anticipated. This confirms the findings of previous literature, which emphasizes the U.S.'s leadership in employing high-tech systems for surveillance and enforcement. In contrast, Mexico and Chile show more limited technological implementations, which is consistent with expectations drawn from the literature. While both countries have adopted some advanced tools, their scope and integration into migration governance are far less extensive compared to the U.S. This finding matches the research premise that countries with less developed infrastructure face challenges in deploying technology at a comparable scale. Honduras, as predicted, represents an even more technologically underdeveloped context, lacking significant resources for managing migration through advanced technology. This reinforces the conclusion that countries with limited technological capacity face greater challenges in migration governance, as outlined in the methodology.

5 Discussion and conclusions

According to the findings of this research, there is evidence that technology applied in migration processes in the Americas has primarily focused on surveillance and control, functioning as a tool of power and discipline, affecting both migrants and host societies. This approach is more evident in countries like the United States, where technological development is more advanced. The data also show significant ambivalence: it can facilitate both exclusion and social integration. For instance, in the U.S., advanced technological tools—including mobile apps, facial recognition systems, emotion detection, and drones— not only expedite migration governance but also intensify control over migrants. These practices reflect Michel Foucault's concept of "biopower," which describes how control shifts from mere territorial management to the governance of populations, disciplining and shaping behaviors to subjugate those on the margins of society (Foucault, 1975).

In Mexico, despite efforts to implement similar technologies, insufficient technological landscape limits their effectiveness compared to the United States. This situation is similar in Chile, where technological disadvantages are also faced. However, an exception is the "Migrapp" application, which promotes social integration with the support of non-governmental organizations, in a context generally dominated by the use of technology for exclusion, generated and enhanced by civil society and international organizations. On the other hand, Honduras is in an even more unfavorable situation due to the general lack of human and technological resources, further exacerbating the vulnerability of its migrant population in the face of digitized migration processes in northern countries.

It is at this point that it becomes crucial to reflect on the concept of "social technologies," introduced in this article, as those designed to promote inclusion and social wellbeing. However, the technologies analyzed in this study diverge from this ideal, perpetuating dynamics of exclusion and control instead. This paradox not only affects migrants but also governmental institutions and their public policies, transforming migration control into a "total social fact" that, as Ramonet (2020) describes, destabilizes not only social and political expectations but also conceptions about vulnerable populations. In this framework, migrants are simultaneously perceived as a threat and as a group in need of differentiated help, reinforcing technology as a tool of power (Méndez-Fierros, 2023).

To better understand these dynamics, it is useful to turn to thinkers like Mbembe (2003), who analyzes how power subjects entire populations to what he calls a "zone of non-being", and Butler (2020), who highlights how these practices reinforce the exclusion and dehumanization of migrants. Additionally, Deleuze (1992) suggests that these technologies represent a new phase in the evolution of control societies, where power infiltrates all spheres of social life.

The growing dependence on surveillance and control technologies in migration governance poses significant risks not only to human rights but also to the social structure of the societies involved. The lack of transparency and adequate regulation allows these technologies to perpetuate biases, discriminate, and reinforce existing hierarchies, transforming migrants into subjects of control that transcends the legal and punitive, penetrating the social and personal spheres of individuals.

However, the solution does not lie in eliminating technology but in ensuring that its development and use in the migration field are responsible and aligned with human rights principles. To achieve this, governments and society as a whole must adopt a forward-looking perspective, anticipating the challenges and opportunities presented by increasing digitalization.

Governments like that of the United States, with advanced technological capabilities, have the opportunity to lead with transparency and fairness, implementing these tools in a just and ethical manner. Mexico and Chile, for their part, must strengthen their technological landscape and regulatory frameworks to manage migration efficiently and with respect for rights, avoiding the creation of digital divides that exacerbate vulnerabilities. Honduras, in turn, must prioritize the development of its technological capacities to manage migration from a proactive rather than reactive stance.

The call is for global technological governance where innovation does not become an instrument of exclusion, but instead becomes technology for social wellbeing. Only through a shared vision and joint action can we build futures where technology, instead of deepening inequalities, becomes a bridge toward safer, more orderly, and dignified migration.

Author contributions

JC-M: Conceptualization, Investigation, Writing – original draft, Writing – review & editing, Data curation, Formal analysis, Funding acquisition, Methodology, Project administration, Resources, Software, Supervision, Validation, Visualization. IM: Writing – original draft, Writing – review & editing, Conceptualization, Data curation, Formal analysis, Investigation, Supervision, Validation. AD: Writing – original draft, Writing – review & editing, Data curation, Formal analysis, Investigation, Methodology, Validation. IC: Writing – original draft, Writing – review & editing, Data curation, Formal analysis, Investigation, Validation.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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