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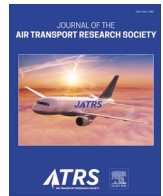
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# eGates in airports: A systematic literature review and future research directions

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## ABSTRACT

This paper offers the first systematic literature review of eGates in airports. It does so in the context of air transport research's need to engage with wider debates concerning the design, implementation and use of digital work at airports. Moreover, it demonstrates the key contextual, methodological and thematic trends and provides future research directions. It is based on a thorough search of publications in earlier literature reviews, the Scopus database, and Google Scholar, using the PRISMA 2020 guidelines. The search revealed 258 records, with 40 publications meeting the inclusion criteria. The identified literature spans across two decades 2004-2025 and represents a multi-cultural stream of research. It includes multi-disciplinary contributions from three actors: the machine, passengers and human operators (guards). Bringing together insights from these different actors helps connect different views and fosters understanding across disciplines. Future research should strive to implement mixed method research designs, adopt extended technology acceptance conceptualisations and acknowledge the importance of the human factor in eGates design, implementation, operation and development.

## 1. Introduction

In recent decades, airports have evolved from simple transport hubs into intricate business platforms. Enhancing the passenger experience has become a central focus of airport management (Sun et al., 2025). Digital innovations play a crucial role in this enhancement, impacting every stage from departure to arrival. This encompasses airport arrival, check-in, baggage drop, security screening, boarding, on-board, transfer, border control/immigration and baggage collection (Wandelt et al., 2024; Thums et al., 2023). Of particular importance is the enhancement of passengers' experience during the border control process. The International Air Transport Association (IATA) conducted a global passenger survey in 2023, sampling 8,000 individuals from 140 countries (IATA, 2024). The findings revealed that many respondents felt there was "too much time spent at border control."

An increasing number of countries are taking steps to address this concern. For example, the United Kingdom is deploying over 200 eGates across 13 airports. Each airport terminal features a 'Principal Control Point' (PCP), which includes two areas (see Fig. 1): (a) desks for officers to interact one-on-one with passengers and (b) automated 'eGates'. One officer can supervise up to 10 eGates simultaneously (Gardner 2023). eGates are automated systems that utilise biometric checks, such as

facial recognition or fingerprint scans, and verify biographic details from travel documents (Mäkelä, 2024).

The verification process involves the e-gate scanning the digital data from an ePassport, capturing the passenger's unique biometric samples, and comparing the live data with the ePassport information. Once a match is confirmed, further checks are conducted at other security points, streamlining the process and reducing the need for repeated identity document checks (Khan & Efthymiou, 2021).

The eGate system serves as a decision support assistant (Gorodnichy et al., 2014), aiding in identity verification through biometric features from e-passports and assessing risks by analysing all available data. This system provides insights that facilitate smoother clearance and informed decision-making, resulting in strong recommendations that highlight the semi-automated nature of border control. If a passenger requires a manual check, the system acts as a behavioural assistant (Gorodnichy et al., 2014). Biometric recognition can optimise resource utilisation in airports, enhancing safety and passenger enjoyment by significantly reducing processing times (Sun et al., 2024).

While the benefits of sharing biometric data are apparent for both the airport and the passengers, the process of storing and using personal data perceived as sensitive can create complexities exacerbating passengers' concerns over data privacy (Culhane, 2014; Ioannou et al.,

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2020). According to IATA’s Global Passenger Survey (IATA, 2024) participants are hesitant to use biometric systems due to concerns about (a) data breaches, (b) data being shared with other organisations, (c) not knowing how long data will be stored and (d) not knowing how data can be deleted. These concerns can heighten the risk of rejection, potentially leading to the failure of the sustainable implementation of eGates in airports. Moreover, it can alter the positive passenger experience, and the benefits associated with it including the generation of non-aviation revenues (Fasone et al. 2016), likelihood of positive word-of-mouth (Wattanacharoensil et al., 2016), airport reuse (Hong et al., 2020) and airport competitiveness (Batouei et al., 2020). Such benefits include, generating non-aviation revenue (Fasone et al., 2016), encouraging positive word-of-mouth (Wattanacharoensil et al., 2016), promoting airport reuse (Hong et al., 2020) and enhancing airport competitiveness (Batouei et al., 2020).

Currently, there is limited academic literature on the design and use of eGates in airports. To our knowledge, no systematic review or evidence synthesis exists on this subject. Recent literature reviews on airports, such as those by Bahnman (2023), Thums et al. (2023), and Wandelt et al. (2024), do not address studies on eGates. Our aim is to offer the first systematic literature review of eGates in airports. The review has three primary objectives (a) assess the level of academic interest in the topic, (b) synthesise trends in context, methods, and themes and (c) suggest directions for future research. To achieve this, we have formulated the following review questions:

**RQ1.** What are the central identity characteristics of the literature (Contextual)?

**RQ2.** How was the relevant research conducted (Methodological)?

**RQ3.** What are subjects and topics of the literature (Thematic)?

This paper is structured as follows: Section 2 outlines the methodology based on the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA 2020) guidelines (Page et al., 2021). Section 3 discusses the identity traits of the literature (research objective 1)

and synthesise its contextual, methodological, and thematic trends in two phases: 2004-2014 and 2015-2025 (research objective 2). Section 4 proposes future research directions (research objective 3). Finally, Section 5 highlights the contributions of the systematic literature review, covering conceptual, methodological, and empirical aspects, while also addressing its limitations.

**2. Method**

The systematic literature review adheres to the PRISMA 2020 statement (Page et al., 2021), which includes a checklist of 27 items and a flow diagram outlining three steps: identification, screening, and inclusion. The updated PRISMA 2020 guidelines reflect recent advancements in systematic review practices, aiming for enhanced transparency and consistency in our methods. This approach aligns with recommendations from scholars in the field advocating for protocols like PRISMA to improve clarity (e.g., Palmer, 2025; Papavasileiou et al., 2025).

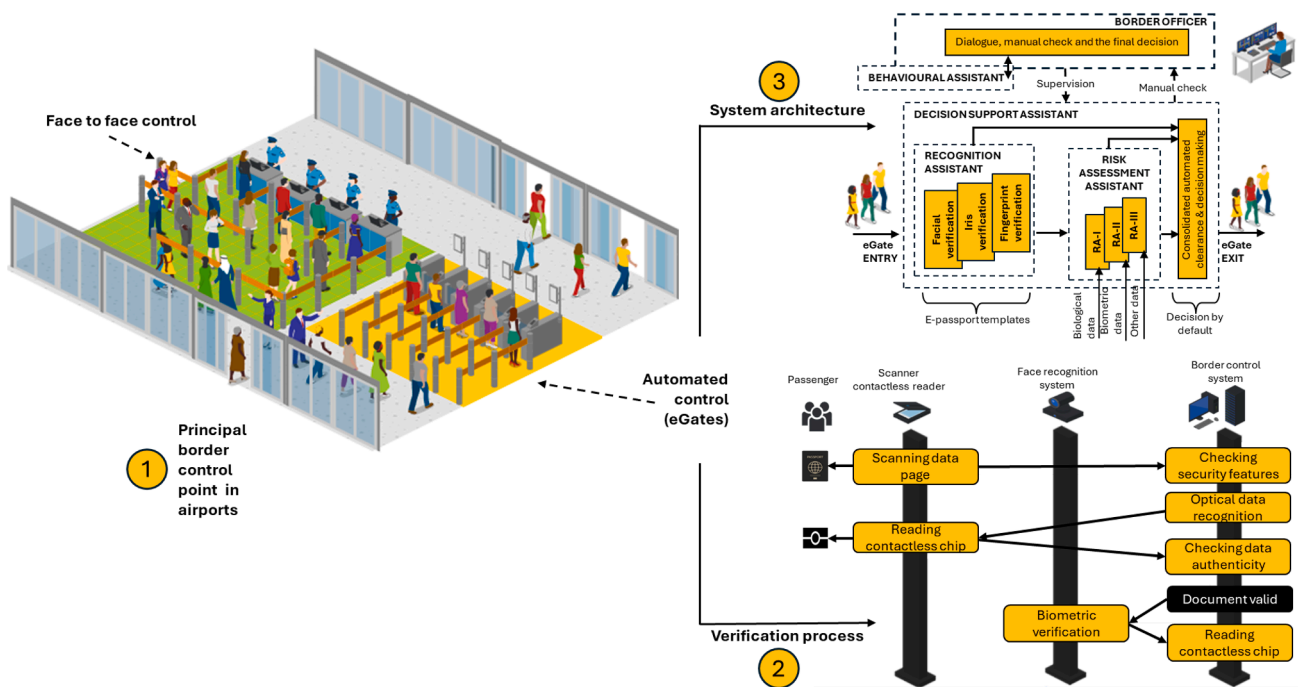
**2.1. Eligibility principle**

To be included in the review, the following criteria must be met by the studies: (a) the focus must be on eGates in airports, (b) it should be published in English, and (c) it must appear in peer-reviewed journals, conference proceedings, or book chapters (see Fig. 2).

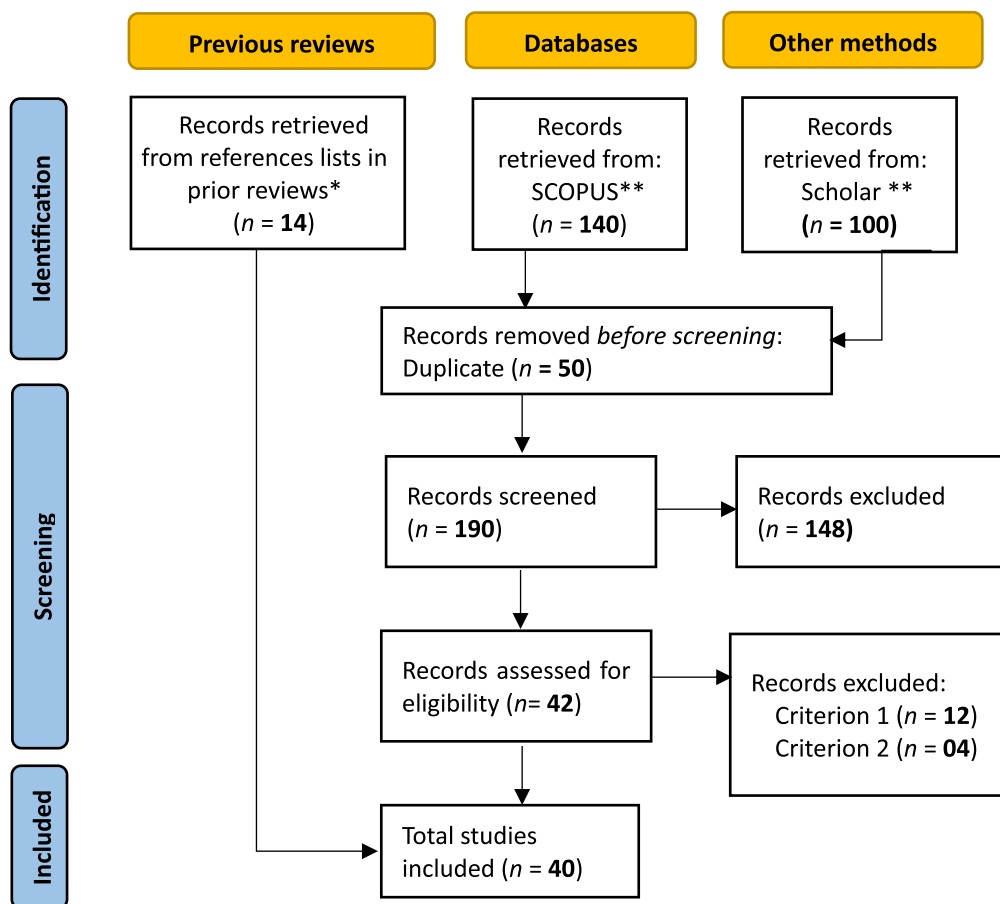
**2.2. Identification**

Using this eligibility principle, we implemented a three-stage search strategy (see Papavasileiou et al, 2025). First, we hand-searched the reference lists of previous literature reviews relevant to our topic. We reviewed these studies in the following order: (a) Labati et al’s (2016) narrative review of biometric technology for border control, (b) Koroniotis et al’s (2020) review of cybersecurity in smart airports, (c) Chaki and Ashour’s (2021) review of border control systems, and (d) Hidayat et al’s (2024) recent review on facial recognition for border control.

This process yielded 14 records that qualified for inclusion (see



**Fig. 1.** Principal border control point in airports and automated eGate system architecture and process. Source: own elaboration; Note: 2 developed from Nguyen et al (2019); 3 developed from Gorodnichy et al (2014).



**Inclusion/exclusion criteria:** A study related to eGates (*Criterion 1 - CR<sub>1</sub>*), within the context of airports (*Criterion 2 - CR<sub>2</sub>*),

Database	Search string	Limits	
Scopus	ALL ( "egate" OR "e-gate" AND "airports" ) AND ( LIMIT-TO ( LANGUAGE , "English" ) )	Source	Peer-reviewed articles book chapters & conference articles
		Language	English
		Period	No limit
Google Scholar	{"egate" OR "e-gate" AND "airports"}	Source	Peer-reviewed articles book chapters & conference articles
		Language	English
		Period	No limit

**Fig. 2.** PRISMA flow diagram and search strategy for capturing literature on eGates in airports. **Source:** develop from Page et al (2021) **Note:** \* Chaki and Ashour (2021); Hidayat et al (2024); Koroniotis et al (2020); Labati et al, (2016); \*\*Last search 02 May 2025.

Fig. 2). Next, we focused on publications indexed in Scopus, using the search string “e-gate” OR “egate” AND “airport” across all fields. This approach revealed 140 records (see Fig. 2). Following recent efforts (e.g., Sun et al, 2024; Wandelt et al, 2025), we conducted a complementary search in Google Scholar (see Fig. 2), retrieving the first 100 results (see Papavasileiou et al, 2025) using the same search string and criteria.

### 2.3. Screening

We reviewed the 240 publications for duplicates prior to screening

titles and abstracts, eliminating 50 duplicates. This left 190 publications, which the first and third authors screened independently, with the second author resolving any conflicts. Through this process, we agreed to exclude 149 publications from further review.

Next, we examined the full texts of the remaining 41 publications against the eligibility principle: studies on eGates in airports (see Appendix A). During this review, we identified 14 publications that initially appeared relevant but were not upon closer examination. For instance, Halpern et al. (2021a) discuss e-gates in the broader context of overall airport digital maturity rather than focusing solely on e-gates.

Similarly, Kim et al. (2023) explore factors influencing travellers' choices to use the complete airport biometric system instead of just e-gates.

As a result, we will concentrate on the 40 studies that meet the inclusion criteria.

## 2.4. Data extraction

In accordance with Papavasileiou et al. (2025), we employed a standardised data extraction matrix to assist in answering our review questions and achieving our research goals (see Table 1). Initially, we extracted contextual data, including (a) authorship (e.g., country of affiliation), (b) type of publication (e.g., journal article, conference proceedings, or book chapter) and (c) related discipline (e.g., air transport or information technology). Next, we gathered methodological elements, examining research design, such as experiments and mixed methods, as well as the type of analysis, including simulation and qualitative comparative analysis. Finally, we categorised the thematic items by topic, such as performance assessment and intention to use, and by subject, including machines, passengers, and human operators.

## 3. Synthesis of key trends

The literature on eGates in airports spans two decades. In the first phase, from the seminal article by Daugman (2004) to 2014, a total of ten studies were published. In the second phase, from 2015 to early 2025, publications tripled, reaching 30. To illustrate this growing interest, we outline key insights regarding the main actors: the machine, passengers, and human operators (see Fig. 3).

### 3.1. Machine

Fig. 3 illustrates that the topic of eGates in airports has predominantly been examined from a machine perspective, focusing on two primary areas: system architecture and performance assessment.

#### 3.1.1. System architecture

In the first decade, four studies investigated the system architecture of eGates. In the beginning, Daugman (2004) detailed the iris recognition system implemented at seven airports in the UAE. Before the end, Cantenero et al. (2013) emphasised the advantages of a multi-modal architecture for verifying passenger biometric identities, using data from Barajas and El Prat international airports in Spain. Initially, only 85.45 % of passengers could access the eGate system. However, after incorporating multimodal biometric verification, the overall biometric error rates decreased to 4.78 %, leading to an increase in system usage to 95.22 % of passengers. In the same year, Schreiber et al. (2013) introduced a multisensory surveillance eGate system, used at Vienna International Airport in Austria, demonstrating its capability to count individuals inside the eGate and detect any unattended luggage, ensuring that only one passenger was present and that no items were left behind. The following year, Gorodnichy et al. (2014) characterised eGate architecture as a decision support tool for airport border control guards.

In the second decade, research on eGate systems nearly tripled. It commenced with Del Rio et al.'s (2015) analysis of common eGate systems across various airports. In 2019, Nguyen et al. presented a passenger reauthentication system designed to enhance security and convenience at eGates.

Zhou and Wang (2020) and Shi et al. (2021) reported on face recognition trials conducted at Hohhot Baita International Airport in China. Lin and Hung (2021) shared findings from a fingerprint sensing system at Kaohsiung International Airport in Taiwan. The following year, Dvořáková et al. (2022) proposed a simulation model for a generic eGate, suitable for arrival border control at any airport. More recently, Alkheder et al. (2024) examined the impact of a new eGate design on

passenger flow at Terminal 4, Kuwait International Airport. Also, Sawicki and Sawicka (2025) presented a comprehensive method for redesigning airport border control procedures in Western Europe.

Overall, this body of research indicates that the eGate system can reduce human error, alleviate guard workload, and expedite passenger wait times at border control.

#### 3.1.2. Performance assessment

In the first decade, two studies dealt with the performance of the eGate system. MacLeod and McLindin (2011) proposed a systematic approach to evaluate passenger processing within the eGate's operational environment, whether introducing a new system or comparing it with an existing one. Spreuwers et al. (2012) studied image quality and face recognition at Schiphol Airport in the Netherlands over a two-week period, analysing data from approximately 950 passengers at two different eGates. They discovered that nearly five percent of the images encountered significant issues, including poor or excessive contrast, dust and hair in photos, cracks, compression artifacts, poor scan lines, colour smudges, stains, non-frontal poses, and blurred images.

In the second decade, interest in this area increased, with the number of relevant publications rising to 11. Opitz and Kriechbaum-Zabini (2015) evaluated the eGate system at Vienna International Airport, collecting data over a year, with two out of three systems achieving error rates below Frontex's recommended thresholds. In 2016, Anand et al. conducted a technology evaluation of popular score-level techniques for multimodal biometric fusion. Del Rio et al. (2016) assessed a face recognition system utilising halogen, white LEDs, near fluorescence, or infrared illumination, revealing that learning-based methods, such as the likelihood ratio, demonstrated the highest accuracy, with halogen illumination outperforming all other configurations. Additionally, Robertson et al. (2016) evaluated the eGate system at Auckland Airport in New Zealand, using real operational scenarios to identify issues with system performance and user interaction, as well as potential processing faults.

The following year, Del Campo et al. (2017) evaluated the security of the eGate system at Adolfo Suárez Madrid-Barajas Airport in Spain, focusing on the biometric subsystem's response to presentation attacks. Keshtgar et al. (2019) interviewed 50 patients regarding how orthognathic surgery affected their identification at eGates in airports, with most reporting difficulties during automated checks due to discrepancies between the biometric data in their e-passport chip and live scans.

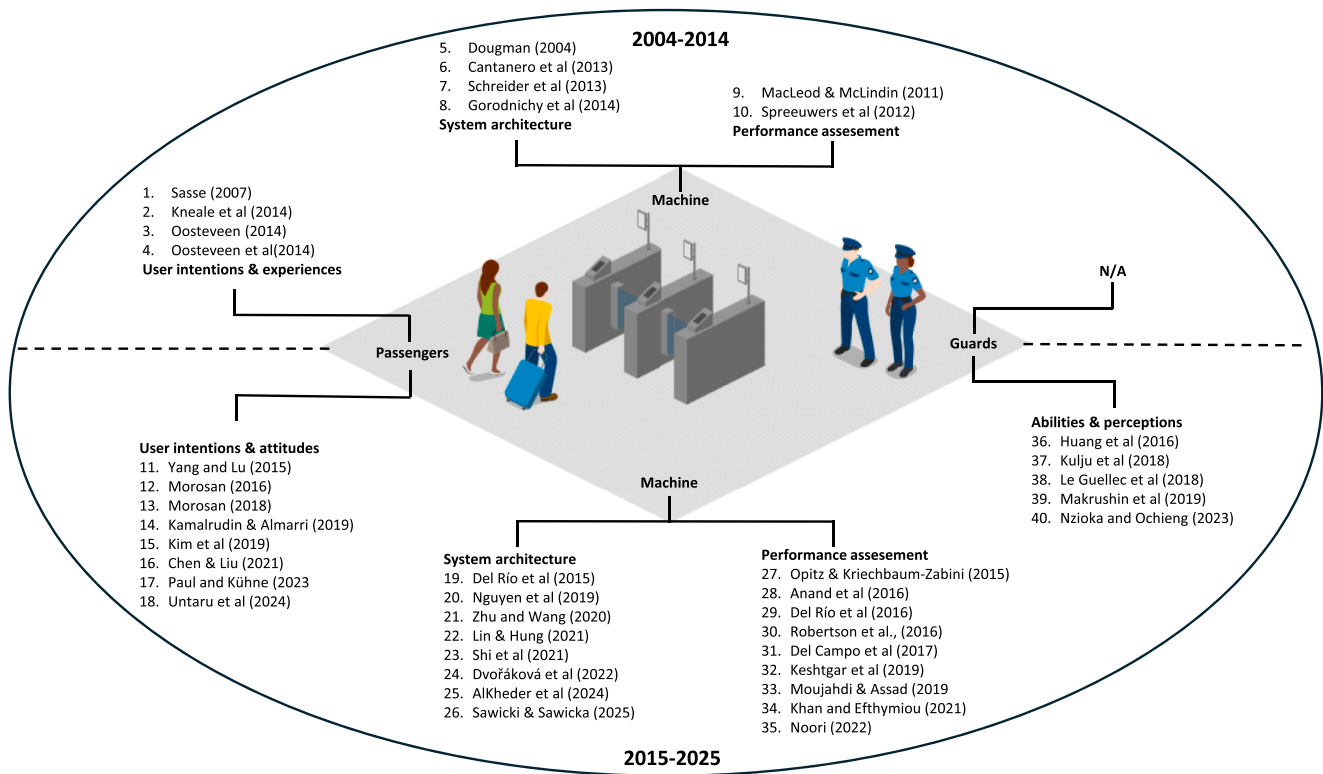
Also, Moujahdi and Assad (2019) presented experimental results from a targeted attack against security applications, comparing passengers' live faces with stored images in their e-passports. More recently, Khan and Efthimiou (2021) evaluated the Biometric Entry-Exit Program at Dublin Airport in Ireland, where interviews with biometric experts and trial results indicated good technical match rates, although biometric confirmation rates required improvement. Also, Noori (2022) studied the eGate system at Frankfurt Airport in Germany, finding socio-technical issues stemming from its use through document analysis and participant observation.

Overall, this body of the literature suggests that evaluating user behaviour for each task is crucial in mapping out all possible scenarios within the eGate system, essential for configuring and adapting system responses (Robertson et al., 2016). Furthermore, evaluations should consider both technical performance and human factors, aiding in understanding overall system effectiveness and identifying areas for enhancement (MacLeod & McLindin, 2011). Attention should also be given to gaps in stakeholder support, infrastructure, network connectivity, passenger privacy concerns, and the strong reliance on airlines (Khan & Efthimiou, 2021). From a security perspective, eGates must improve attack detection, verifying passengers through two methods: comparing the captured image with the self-enrolment photo and checking it against the passport image (Del Campo et al., 2017).

**Table 1**  
The characteristics of the literature on eGates in airports (2004-2025).

Study	RQ <sub>1</sub> Contextual		RQ <sub>2</sub> Methodological		RQ <sub>3</sub> Thematic	
	Publication	Discipline	Design	Analysis	Subject	Topic
Dougan (2004)	IAR	Air Transport	Conceptual	Schematic	Machine	System architecture
Sasse (2007)	IEEE Security & Privacy	Information Technology	Field study	Narrative	Passengers	User experiences
MacLeod and McLindin (2011)	Book chapter	Defence	Conceptual	Schematic/narrative	Machine	Performance assessment
Spreeuwers et al. (2012)	IEEE (BIOSIG)	Biometric	Experiment	Experimental analysis	Machine	Performance assessment
Cantarero et al. (2013)	IEEE (IESIC)	Information Technology	Conceptual	Archival data	Machine	System architecture
Schreiber et al. (2013)	IEEE (AVSS)	Information Technology	Experiment	Experimental analysis	Machine	System architecture
Kneale et al. (2014)	Aviation	Air Transport	Quantitative(survey)	Descriptive	Passengers	Ease of use (young vs old)
Oostveen (2014)	VISIGRAPP	Computer Science	Field study	Narrative	Passengers	Intention to use
Oostveen et al. (2014)	IHCI	Computer Science	Field study	Narrative	Passengers	Ease of Use
Del Río et al. (2015)	IEEE (SysCon)	Systems engineering	Conceptual	Comparative	Machine	System architecture
Opitz & Kriechbaum-Zabini (2015)	IEEE (AVSS)	Surveillance	Feasibility study	Scenario testing	Machine	Performance assessment
Yang and Lu (2015)	JOTR	Tourism	Quantitative(survey)	SEM	Passengers	Intention to use
Anand et al. (2016)	IEEE (BIOSIG)	Biometric	Experiment	Experimental analysis	Machine	Performance assessment
Del Río et al. (2016)	CS	Computer Science	Experiment	Experimental analysis	Machine	Performance assessment
Gorodnichy et al. (2014)	IEEE (CIBIM)	Biometric	Conceptual	Schematic/narrative	Machine	System architecture
Huang et al. (2016)	JATM	Air Transport	Simulation study	Simulation	Guards	Manpower shortage
Morosan (2016)	JATM	Air Transport	Quantitative(survey)	SEM	Passengers	Intention to use
Robertson et al. (2016)	IEEE THMS	Computer Science	Field study	Observation & questionnaire	Machine	Performance assessment
Del Campo et al. (2017)	IEEE (ICETE)	Information Technology	Experiment	Experimental analysis	Machine	Performance assessment
Kulju et al. (2018)	IFIP (HWID)	Information Technology	Field study	Interviews & observations	Guards	Training/activities
Le Guellec et al. (2018)	AHFE	Ergonomics	Field study	Interviews & observations	Guards	Training/activities
Morosan (2018)	JTR	Tourism	Quantitative(survey)	SEM	Passengers	Information disclosure
Kamalrudin & Almarri (2019)	IJTRE	Computer Science	Quantitative(survey)	Descriptive	Passengers	User experience
Keshtgar et al. (2019)	BJOMS	Medicine	Qualitative (interviews)	Descriptive	Machine	Performance assessment
Kim et al. (2019)	Sustainability	Sustainability	Quantitative(survey)	Qual. Comparative Analysis	Passengers	Intention to use
Makrushin et al. (2019)	VISIGRAPP	Computer Science	Experiment	Simulation	Guards	Computer-aided support
Moujahdi and Assad (2019)	IJCDS	Computer Science	Experiment	Experimental analysis	Machine	Performance assessment
Nguyen et al. (2019)	IEEE (HST)	Information Technology	Experiment	Experimental analysis	Machine	System architecture
Zhu and Wang (2020)	JPCS	Physics	Experiment	Experimental analysis	Machine	System architecture
Chen and Liu (2021)	IJBM	Business	Quantitative(survey)	SEM	Passengers	Intention to use
Khan and Efthymiou (2021)	IJIMDI	Information Technology	Qualitative (interviews)	Thematic/ trial testing	Machine	Performance assessment
Lin and Hung (2021)	SM	Sensing technology	Experiment	Experimental analysis	Machine	System architecture
Shi et al. (2021)	CESBB 2020	Surveillance	Experiment	Experimental analysis	Machine	System architecture
Dvořáková et al. (2022)	IEEE (NTCA)	Air Transport	Simulation study	Simulation	Machine	System architecture
Noori (2022)	Geopolitics	Geopolitics	Conceptual	Documents & observation	Machine	Performance assessment
Nzioka and Ochieng (2023)	RJSSH	Information Technology	Quantitative(survey)	Descriptive, regression	Guards	Enhancing security
Paul and Kühne (2023)	TECNOSCIENZA	Science & Technology	Technographic study	Observations & interviews	Passengers	Human-machine interaction
AlKheder et al. (2024)	CSTP	Transport	Simulation study	Simulation	Machine	System architecture
Untaru et al. (2024)	TPD	Tourism	Quantitative(survey)	SEM	Passengers	Attitudes towards use
Sawicki and Sawicka (2025)	Archives of Transport	Transport	Simulation study	Simulation & MCDA	Machine	System architecture

**Source:** Own elaboration; **Note:** dotted line separates the table into two decades: 2004-2014 & 2015-2025; **IAR**=International Airport Review **CSTP**=Case Studies on Transport Policy; **IEEE** =Institute of Electrical and Electronics Engineers; **BIOSIG**=International Conference of the Biometrics Special Interest Group **Biometrics Special Interest Group**; **EISIC**=European Intelligence and Security Informatics Conference **IJBM**=International Journal of Business and Management; **ICETE**=International Joint Conference on e-Business and Telecommunications; **SysCon**=International Systems Conference; **CS**= Computers & Security; **NTCA**= International Conference on New Trends in Civil Aviation; **CIBIM**= International Conference on Computational Intelligence in Biometrics and Identity Management; **MCSIS**=Multi Conference on Computer Science and Information Systems; **JATM**= Journal of Air Transport Management; **IJRTE**=International Journal of Recent Technology and Engineering; **BJOMS**=British Journal of Oral and Maxillofacial Surgery; **IJIMDI**=International Journal of Information Management Data Insights; **IFIP**= International Federation for Information Processing; **HWID**=International Conference on Human Work Interaction Design; **AHFE**=International Conference on Applied Human Factors and Ergonomics; **SM**=Sensors & Materials; **VISIGRAPP**=International Conference on Computer Vision, Imaging and Computer Graphics Theory and Applications; **ICHI**=International Conference on Interfaces and Human Computer Interaction **JTR**=Journal of Travel Research; **IJCDS**=International Journal of Computing and Digital Systems; **HST**=International Conference on Technologies for Homeland Security; **RJSSH**=Reviewed Journal of Social Science & Humanities; **AVSS**= International Conference on Advanced Video and Signal Based Surveillance; **TECNOSCIENZA**=Italian Journal of Science & Technology Studies; **THMS**=Transactions on Human-Machine Systems; **TPD**=Tourism Planning & Development; **JOTR**=Journal of Tourism and Recreation; **JPCS**=Journal of Physics: Conference Series; **N/A**=Not Applicable; **SEM**=Structural Equation Modelling; **MCDA**=Multi Criteria Decision-Making Analysis; **CESBB**=China's e-Science Blue Book 2020



**Fig. 3.** Thematic trends based on the topic and the subject of the study.  
**Source:** own elaboration; N/A= Not applicable

### 3.2. Passengers

In the first decade, the focus was on passengers' experiences with the eGate system. In the beginning, [Sasse \(2007\)](#) shared insights from his experience at London Heathrow, including interviews with passengers at Schiphol Airport in the Netherlands. At the end, [Oostveen \(2014\)](#) and [Oostveen et al. \(2014\)](#) conducted field studies involving face-to-face surveys and observations of eGates at two major airports in Northern Europe. The first study identified a taxonomy of non-users, comprising of resisters, rejecters, the excluded, the expelled, and the unaware. The second study compared the ease of use across different systems. Also, [Kneale et al. \(2014\)](#) examined the impact of age on eGate usage at Melbourne's Tullamarine Airport, assessing usage rates, time, usability, satisfaction, and overall ease of use.

In the second decade, researchers employed more sophisticated analytical techniques, such as structural equation modelling. For example, some studies investigated factors influencing the intention to use eGates, gathering data through face-to-face surveys at Taoyuan International Airport in Taiwan ([Chen & Liu, 2021](#); [Yang & Lu, 2015](#)) and online surveys with passengers in the United States ([Morosan, 2016](#)). [Morosan \(2018\)](#) explored the factors influencing the willingness to share biometric information at eGates. [Untaru et al. \(2024\)](#) examined the elements shaping attitudes towards biometric technologies at Gimpo International Airport and Jeju International Airport in Seoul, South Korea. Additionally, [Kamalrudin & Almarri \(2019\)](#) investigated the challenges faced by passengers at Dubai Airport when using eGates.

Overall, this stream of literature indicates that a positive passenger experience necessitates both security and convenience systems, such as eGates ([Sasse, 2007](#)). This is because perceived convenience is associated with the intention to use eGates ([Chen and Liu, 2021](#)) and attitudes towards biometric technologies at airports ([Untaru et al., 2024](#)). Also, perceived convenience significantly influences the intention to use eGates, more so than perceived ease of use or usefulness ([Chen & Liu, 2021](#)).

The perceived ease of use and usefulness also correlate with the intention to use eGates ([Chen & Liu, 2021](#); [Morosan, 2016](#); [Yang and Liu, 2015](#)). In fact, performance expectancy (usefulness) and effort expectancy (ease of use) exert a stronger influence than privacy concerns on this intention, with privacy concerns having the least impact on sharing biometric information at eGates. ([Morosan, 2018](#)).

The findings also suggest several potential factors affecting eGate usage at airports, including human operators, prior experience, and age. [Yang and Lu \(2015\)](#) found a link between perceived risk and eGate usage, noting that new users or those who had never tried eGates were less inclined to utilise them. The absence of staff assistance was a key reason for the low interest in using eGates at Dubai Airport ([Kamalrudin & Almarri, 2019](#)). Furthermore, passengers aged 16 to 44 were more likely to use eGates than those aged 45 and older ([Kneale et al., 2014](#)).

### 3.3. Human operators

In the first decade, as we discussed earlier, the literature paid attention solely on the interaction between passengers and the machine in eGates. This focus shifted in the second decade, with five studies examining the topic from the perspective of human operators. [Huang et al. \(2016\)](#) aimed to determine the optimal number of immigration officers for eGates at Taiwan Taoyuan International Airport, concentrating on maintaining passenger wait times within acceptable limits. They employed system simulation, Delphi interviews, and a heuristic algorithm, concluding that over 97.99 % of immigration officers were required, while their work hours could be reduced by more than 54.68 %.

In 2018, two studies presented findings from field research, utilising semi-structured interviews and observations across six European countries as part of the BODEGA project, which aims to enhance human performance in border control. [Le Guellec et al. \(2018\)](#) highlighted the need for guards to remain adaptable in managing dynamic situations during their daily tasks, noting that change management and training

for border guards often lag behind technological advancements, which is essential for ensuring they effectively understand and utilise new technologies. Kulju et al. (2018) further developed a Human Factors framework that impacts the performance of border guards and eGate systems. A year later, Makrushin et al. (2019) created a border control simulation, assessing guards' abilities to (a) recognise morphed passport photos and (b) match these photos with passengers' "live" faces. Recently, Nzioka and Ochieng (2023) explored guards' perceptions of eGates, focusing on their role in enhancing security at Jomo Kenyatta International Airport in Nairobi, Kenya. Their findings indicated that incorporating biometric fingerprint technology and automated passport control would bolster airport security.

This part of the literature underscores the necessity for border guards to receive computer-aided support (Makrushin et al., 2019). However, as Le Guellec et al. (2018) noted, the level of trust that border guards have in the automated systems of eGates requires attention. The machine should serve as a tool to assist them while they concentrate on risk assessments during manual checks. The eGates technology must provide border guards with an effective and user-friendly tool for their monitoring and control responsibilities (Kulju et al., 2018). Nonetheless, prioritising the implementation of eGate systems to compensate for the shortage of immigration officers could lead to more efficient and effective border security (Huang et al., 2016; p.43).

**4. Future directions**

Our review indicates that most of the literature on this topic is rooted in the fields of computer science and information technology (see Fig. 4). Contributions from air transportation research remain uneven. In the first decade, there were two contributions from Dougman (2004) and Kneale et al. (2014), accounting for 22 % of the total publications. In the second decade, three contributions emerged from Huang et al. (2016), Morosan (2016), and Dvořáková et al. (2022). Overall, air transport represented 8 % of total publications. The volume of publications nearly quadrupled in the second decade; however, contributions from air transportation remained relatively stable. To address this gap, we propose several research directions for scholars in the field

**4.1. Mixed method research designs**

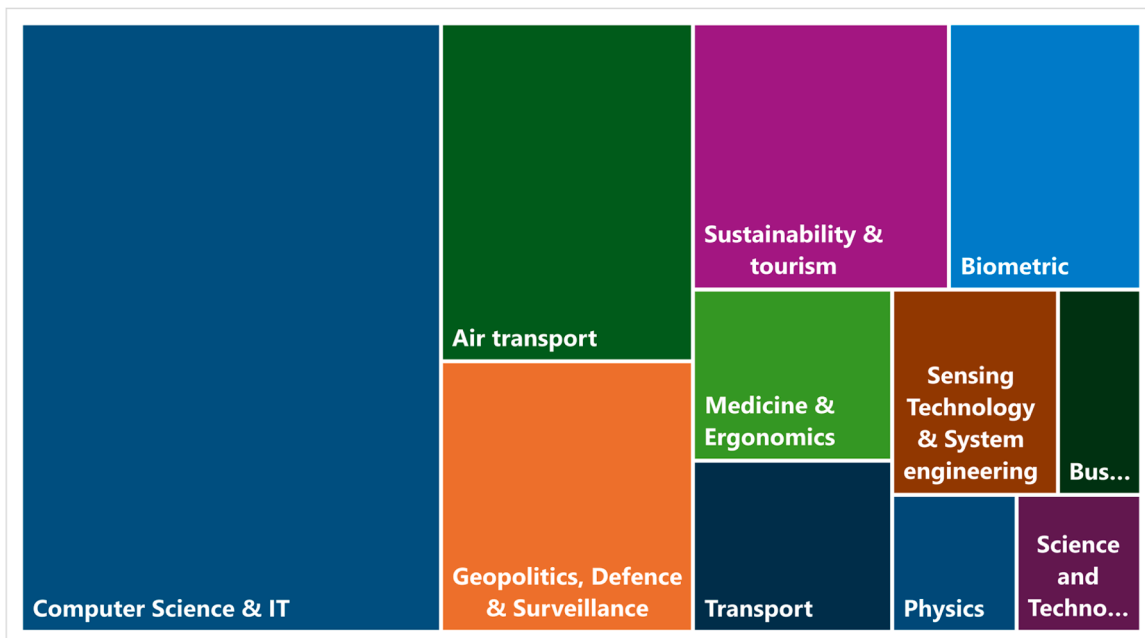
Our review revealed that scholars have employed a range of research designs to explore the topic (see Fig. 5). There was a notable focus on experiments (e.g., del Rio et al., 2016; del Campo et al., 2017) and surveys (e.g., Kneale et al., 2014; Yang & Lu, 2015), with some studies utilising various methods. These include simulation (Dvořáková et al., 2022; Huang et al., 2016), scenario testing (Opitz & Kriechbaum-Zabini, 2015; Robertson et al., 2016) and interviews (Kehshtgar et al., 2019; Khan & Efthymiou, 2021). A common trend across nearly all this literature was reliance on a single method. We encourage future scholars to move beyond this limitation and consider a mixed-methods approach. A prime example is the study by Paul and Kühne (2023), which employed a technographic approach, combining observations and interviews with eGates users. This methodology allows researchers to observe eGates in operation, enabling them to "see technology as an actant in its own right" (Paul & Kühne, 2023), and enrich their understanding with user experiences. This approach will not only enhance the current literature but also contribute to broader discussions in tourism that advocate for a mixed-method approach (Taheri & Okumus, 2024; p.996).

For scholars who prefer a single method, the example of Kim et al. (2023) demonstrates the potential of survey methods combined with Qualitative Comparative Analysis (QCA) to investigate resistance to eGates. Employing QCA in this context will allow researchers to engage with wider discussions in strategic change research, a field that welcomes such contributions (Caputo, 2023; p.106).

**4.2. Technology acceptance conceptualisations**

Our review identified a growing interest in passenger perspectives during the second decade. Early findings from Sasse (2007), Oostveen (2014), and Kneale et al. (2014) were supplemented by insights from nine additional studies. Most of these studies concentrated on the intention to use eGates (e.g., Chen and Liu, 2021; Morosan, 2016; Nzioka and Ochieng, 2023; Untaru et al., 2024). The prevailing argument is that passengers' plans to use eGates are influenced by perceived ease of use and perceived usefulness, grounded in the seminal Technology Acceptance Model (TAM) (Davis, 1989).

We propose that an effective way to expand this concept is through



**Fig. 4.** Contextual trends based on discipline.  
 Source: own elaboration; N/A= Not applicable



Fig. 5. Methodological trends based on research design.  
 Source: own elaboration; N/A= Not applicable

the extended Unified Theory of Acceptance and Use of Technology (UTAUT2) (Venkatesh et al., 2012). UTAUT2 introduces five additional variables to the two commonly used in existing literature: social influence, facilitating conditions, hedonic motivation, price value, and habit. Tamilmani et al. (2021a; p. 989) noted that the predictive capacity of technology acceptance models can vary depending on the context. To our knowledge, no prior study has examined the predictive validity of UTAUT2 in the context of eGates in airports. Testing this hypothesis will aid future researchers in enhancing the current literature and engaging in broader discussions regarding information management. Tamilmani et al. (2021b; p. 12) advocate for the use of UTAUT2 as a foundational

model to explore new technological features and their implications for individual outcomes. eGate represents such a new technological feature.

#### 4.3. Place more attention to guards

Despite advancements in face recognition technology at eGates, guards continue to verify the identities of document holders. The process remains partially automated (Huang et al., 2016; Kulju et al., 2018). At control stations behind eGates, passport officials confirm that the camera image matches the one in each passenger’s passport (Stevens, 2021). If a passenger cannot pass through the eGate, they are directed to a

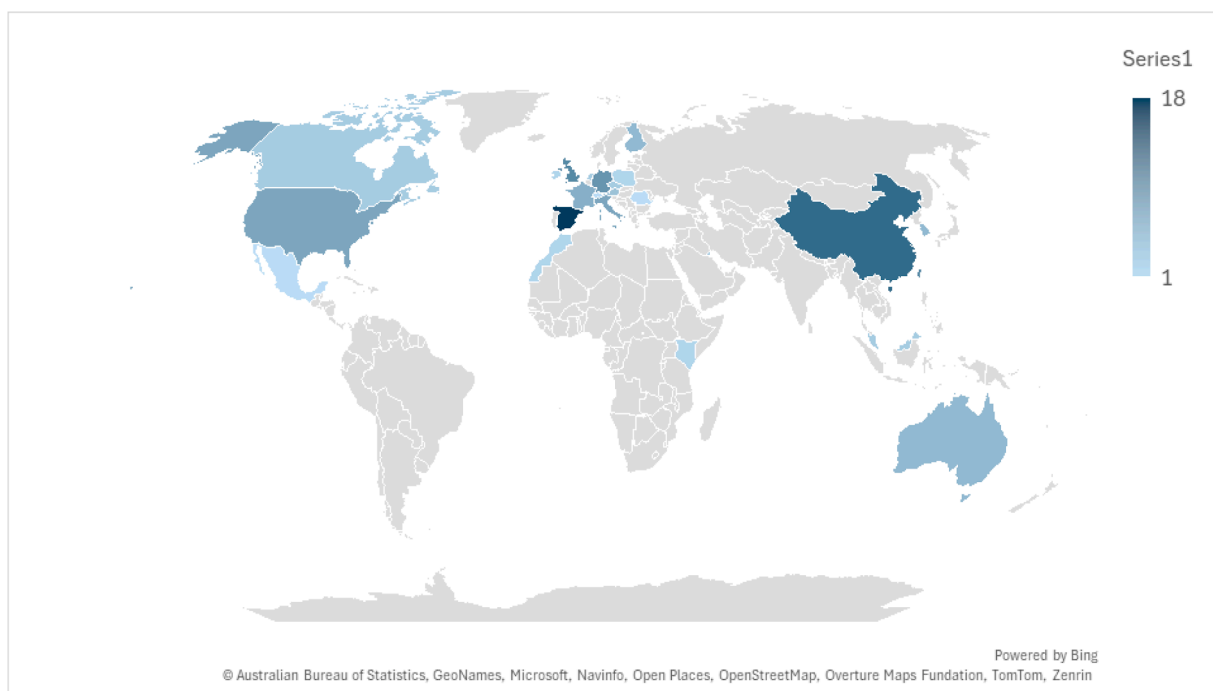


Fig. 6. Contextual trends based on authorship (country of affiliated university).  
 Source: own elaboration; N/A= Not applicable

face-to-face passport checkpoint for further inspection. The passport control officer then verifies the passenger against the passport image and utilises machine document readers and scanners for confirmation. Guards are still responsible for checking the identity of the passport holder and determining their eligibility to enter (Stevens, 2021). Despite their critical role, only 5 % of the literature has focused on guards. We therefore urge future researchers to address this gap by giving more attention to guards in eGates. This will not only enhance existing literature but also contribute to broader discussions on critical infrastructure protection, which emphasises the need for "awareness building and bespoke training" for border guards to identify cybersecurity risks and adopt best practices in their daily operations (Chatzis & Stavrou, 2022; p.13).

## 5. Conclusion

Our review indicates a growing interest in eGates among scholars. A global community of nearly 130 researchers from over 25 countries (see Fig. 6) is engaged in understanding the design, implementation, and use of eGates in airports. Data has been gathered from 13 countries across Europe, Africa, East Asia, Asia, the Middle East, Australia, and New Zealand. Contributions span various fields, including tourism, sustainability, geopolitics, surveillance, physics, biometrics, computer science, information technology, ergonomics, and medicine. However, there is still significant potential for improvement. While the research field is expanding in global reach, methods, and themes, our analysis highlights several gaps.

By following our proposed future directions, scholars can broaden the literature and respond to recent calls from various disciplines. This aligns with the recommendations from Wandelt et al. (2025; p.4), who emphasise the need for future researchers to create work that "brings together insights from existing literature, connects different views, and promotes understanding across disciplines."

Our review provides important empirical, methodological, and conceptual contributions to the literature. Empirically, we present the first comprehensive literature review of eGates in airports, incorporating extensive new research since recent airport studies (e.g., Bahman, 2023; Thums et al., 2023; Wandelt et al., 2024). Scholars interested in this topic may find our analysis beneficial, as we highlight key trends in context, methods, and themes, facilitating navigation of the expanding literature. The contrast in contributions between the first decade (2004-2014) and the second decade (2015-2025) illustrates the evolution of this research.

Methodologically, we aim to build upon previous systematic reviews that focused solely on peer-reviewed articles, referred to as 'white literature' (Adams et al., 2017). We believe that the peer review process reduces errors and serves as a self-regulating mechanism that signals the quality of work (see Soklaridis et al., 2024). Scholars in air transportation are increasingly recognising the necessity of seeking evidence beyond academic journals. For example, Gu et al. (2024) and Holmes et al. (2024) have incorporated 'grey literature' into their systematic reviews, examining the impact of shock events on airport management and climate change risks in Australasian aviation. We assert that including grey literature—material outside traditional peer-review processes (Adams et al., 2017)—in our conference articles and book chapters on eGates in airports is vital for enriching our understanding of the subject.

Conceptually, our review offers a comprehensive overview of the design, use, and implementation of eGates in airports. We propose a framework that encompasses three key actors: machines, passengers, and human operators (guards). Most conceptualisations in the identified literature have concentrated on a single actor. Our three-dimensional framework illustrates the interactions between people and technology, incorporating both passenger and guard perspectives.

However, our review is not without limitations, which we acknowledge. Some records not indexed in the Scopus database may

have been excluded, potentially leading to selection bias in the 40 studies included in the review. This number is comparatively strong against recent systematic literature reviews, where Palmer et al. (2025) included 27 studies and Soklaridis et al. (2024) included 42. Additionally, our review was confined to English publications, which may explain the absence of contributions from South America. Takahashi et al. (2025) noted that South American scholars often publish in Spanish and Portuguese peer-reviewed journals. Future research could address this limitation by following Takahashi et al. (2025) and focusing exclusively on Spanish and Portuguese peer-reviewed journals. Alternatively, researchers could adopt multilingual criteria, as demonstrated by Potin et al. (2024), who searched for articles in English and French. This approach will aid in bringing non-English literature "out of the shadows" (Papavasileiou & Stergiou, 2025).

## CRediT authorship contribution statement

**Emmanouil Papavasileiou:** Writing – review & editing, Writing – original draft, Visualization, Software, Resources, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Alexandros Paraskevas:** Validation, Supervision, Project administration, Data curation. **James Edmunds:** Validation, Supervision, Project administration, Data curation.

## Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

## Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.jatrs.2025.100076.

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