



Towards Smart Airport Management: A Service-Oriented Architecture for Passenger Flow Integration and Travel-Time Prediction

Hacia una gestión inteligente de los aeropuertos: una arquitectura orientada a servicios para la integración de los flujos de pasajeros y la predicción de los tiempos de viaje

Natalia Hustova-Harifulina

University of Malaga, Andalusian Institute for Research and Innovation in Tourism (IATUR), Spain, nhustova@uma.es

Antonio Jesús Guevara-Plaza

University of Malaga, Andalusian Institute for Research and Innovation in Tourism (IATUR), Spain, guevara@uma.es

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Abstract

The continuous growth of global air transport in the era of tourism globalisation and the increasing complexity of airport operations highlight the need for integrated technological solutions that support data-driven management. This study proposes a high-level integrated model that consolidates information from multiple airport systems and enables automated analysis of passenger flows and travel-time prediction. A snowball sampling methodology based on structured interviews with experts at Málaga–Costa del Sol Airport was used to examine the feasibility, requirements, and potential value of implementing such an integrated approach. Drawing on contemporary research in service-oriented architectures, the study outlines a conceptual framework centred on a middleware layer that orchestrates communication between heterogeneous subsystems. The proposed model offers a structured basis for developing more flexible, scalable, and predictive airport management tools. This work contributes to the discussion on digital transformation in complex airport environments, as the findings highlight a clear need to improve the interoperability of systems and data and establish a foundation for future research.

Keywords: Smart Airport Management, Passenger Flow, System Interoperability, Service-Oriented Architecture, Travel Time Prediction.

Resumen

El crecimiento continuo del transporte aéreo mundial en la era de la globalización del turismo y la creciente complejidad de las operaciones aeroportuarias ponen de relieve la necesidad de soluciones tecnológicas integradas que respalden una gestión basada en datos. Este estudio propone un modelo integrado de alto nivel que consolida la información procedente de múltiples sistemas aeroportuarios y permite el análisis automatizado de flujos de pasajeros y la predicción de los tiempos de viaje. Se ha empleado la metodología de bola de nieve basada en entrevistas estructuradas con expertos del Aeropuerto de Málaga-Costa del Sol para examinar la viabilidad, los requisitos y el valor potencial de la implementación de dicho enfoque integrado. Basándose en investigaciones recientes sobre arquitecturas orientadas a servicios, el estudio esboza un marco conceptual centrado en una capa de middleware que coordina la comunicación entre subsistemas heterogéneos. El modelo propuesto ofrece una base estructurada para desarrollar herramientas de gestión aeroportuaria más flexibles, escalables y predictivas. Este trabajo contribuye al debate sobre la transformación digital en entornos aeroportuarios complejos, ya que los resultados ponen de manifiesto una clara necesidad de mejorar la interoperabilidad de sistemas y datos, así como formulan bases para las futuras investigaciones.

Palabras clave: Gestión inteligente de aeropuertos, flujos de pasajeros, interoperabilidad de sistemas, arquitectura orientada a servicios, predicción de tiempos de viaje.

1. Introduction

The airline industry has undergone significant changes over the last few decades (Amadeus, 2017; International Air Transport Association [IATA], 2018), driven, among other causes, by the globalisation of tourism (Dimitriou et al., 2017). Air transport is a fundamental element in the development of tourism (Dimitriou & Aparicio, 2018), as corroborated by statistics indicating that nearly 58% of all tourists reach their destination by air (World Tourism Organisation [UNWTO], 2020). Air connectivity, shaped by airport infrastructure and air routes, is an indispensable part of global social and territorial cohesion and an essential component of a destination's economic prosperity (Air Transport Action Group, 2020; Sartzetaki et al., 2019).

At the European level, in 2024, more than 1 billion passengers used air transport for their travel, representing an increase of more than 50% compared with 2010 (Eurostat, 2025). Passengers' growing interest in the benefits of air transport is confirmed by recent studies from the International Air Transport Association (IATA), which predict that by 2040, the number of global passengers will double from current levels, reaching 8 billion (IATA, 2023). Despite the benefits that aviation brings to global economies (ATAG, 2020) and, specifically, to tourism (IATA, 2018) and to the development of the destinations where it deploys its infrastructure (Bezerra & Gomes, 2019), it currently faces several challenges (Deloitte, 2022).

One of these is undoubtedly the difficulty airports face in coping with growing traffic, due to the aforementioned globalisation of travel, which has increased passenger flows worldwide (Demirel & Cinar, 2025; Yao et al., 2023). This situation can cause



complications in airport resource management and affect the overall passenger experience (Spanish Agency for Standardisation and Certification, 2017). To mitigate the effects of this problem, comprehensive management mechanisms are needed (Dimitriou et al., 2024), helping airports to plan their activities more efficiently and forecast future performance to meet quality and sustainability criteria across all areas.

One of the key elements in achieving this objective is the intelligent management of data, enabled by the interoperability of the various internal and external systems that make up the airports' structure. Current technological resources facilitate this analysis through AI-based processing and interpretation models and their derivative solutions, which are one of the key trends in laying the foundations for intelligent management (Zaharia & Pietreanu, 2018). The main objective of this research is to design an integrated technological architecture for systems that interact with passengers before and during their stay at the airport, based on a feasibility study conducted with sector experts.

The analysis model was developed at Malaga-Costa del Sol Airport, which is part of the AENA network. The snowball sampling method was employed, enabling a thorough compilation of information on the requirements and the current state of integration between data systems through structured interviews with experts at the airport in question. As a result, the sample comprised 10 in-depth interviews, which were subsequently analysed using a coding and tagging system in accordance with Mayring's (2000) methodological recommendations, enabling a clear graphical representation of the main findings. Finally, the data obtained have enabled the design of an SOA-type integrated technology architecture model in line with the definitions of Solarte-Martínez et al. (2021).

2. Literature review

2.1 Technological trends in the air industry

With the notable increase in the number of passengers worldwide (SITA, 2023b), as well as growing air connectivity, it is essential for airports to achieve an optimal competitive position (Amadeus, 2017) among both suppliers and passengers themselves. To this end, airport managers worldwide are increasingly turning to innovation, with technological innovations gaining the greatest importance. According to data from a recent SITA study (2023a), 93% of airports expected to increase spending on technology implementation throughout 2023, while 75% said that investments in this segment grew compared to those recorded in 2022. The authors discuss the potential applications of technology in airport systems, highlighting process automation as a key area on which many researchers agree.

Von der Burg and Sharpanskyh (2025) highlight, in their recent study, the importance of process automation, specifically in the airport environment, to ensure operational efficiency and predictability. Studies on the applicability of automation processes based on intelligent models range from schedule management (Dalmau et al., 2025) and aircraft movements on runways (Röling, 2008) to air traffic control (SESAR JU, 2020) and weather forecasting (Schultz et al., 2021). In turn, the prospect of innovation in the management of processes related to passenger flows is approached from the point of view of the application of intelligent analysis and prediction algorithms such as machine learning applied to the optimisation of specific activities at the airport, such as security control and check-in counters (Rodríguez Sanz et al., 2021), or the study of flight delay cases (Mokhtarimousavi, 2023).

Some authors analyse possible optimisation models in strategic airport planning, for example, data-based real-time airport capacity prediction systems. Specifically, Wang and Zhang (2021) differentiate between scenario-based and machine learning-based methods. The first approach seeks to design arrival capacity distribution profiles over a short period, for example, one day, for use in Ground Delay Programmes. The second approach has been applied, among other cases, to analysing impacts on the airport situation under changing weather conditions, where forecasts are based on historical and other probabilistic data for a given forecast horizon. These machine learning methods have also been discussed by Wang et al. (2023), who note that systematic prediction frameworks are often proposed and applied to different types of data sets within the same analysis, such as air traffic data and weather conditions.

Other studies highlight the relevance of implementing automated and intelligent procedures for measuring service quality at airports, underscoring the importance of assessing an airport as a single system—a key approach in the present research as well. In the studies by Alanazi et al. (2024), machine learning models are applied to analyse passenger sentiment with the aim of improving the organisation and quality of services at airports. Similarly, other authors have incorporated the assessment of the airport as a system comprising different databases and operational centres into their studies to understand and improve its performance. For example, Nayeem et al. (2025) and Scala et al. (2021) discuss simulation methods for modelling interactions and responses to different events at an airport, highlighting dynamic simulations as tools that can help understand the interdependence between events and flows across different subdivisions of an airport.

However, innovation or automation, from the perspective of establishing a technologically interoperable airport model, is rarely addressed in current studies. System interoperability is a key factor in achieving an agile and flexible organisational structure, which in turn enables complete business integration (Vernadat, 2003; Grant & Yeo, 2021). The main advantage of a connected and



integrated organisation is its dynamic structure (Gorton, 2011), which allows new components to be incorporated with remarkable ease and, consequently, new business strategies to be applied (Vernadat, 2004). This study provides a new perspective on innovation planning applicable to airport systems, offering a basic mechanism for achieving optimal results in comprehensive processes for managing knowledge and the status of an airport at any time. The research premise is that interoperability and integration between systems are fundamental to improving performance and service quality in an airport-sized infrastructure.

2.2 State of the art of systems integration architectures

One of the essential steps in achieving the optimal configuration for comprehensive data processing at an airport or across several airports is undoubtedly to integrate the different systems to ensure an automated, seamless flow of data exchange (Bolo, 2006). To this end, transformation processes are often applied, based on new models of software service organisation within the corporate structure (Hustad & Olsen, 2021; Vernadat, 2007). The phenomenon of integration and interoperability has been one of the main challenges of this millennium (Briones-Peñalver et al., 2018). However, most companies have now moved away from traditional monolithic system approaches (Richards, 2022), adopting asynchronous, service-oriented, or message-based techniques (Vernadat, 2007).

Following Richards' (2022) classification, two main architectural styles can be distinguished: monolithic, which refers to a single deployment unit, and distributed, which uses multiple service-based systems. Despite the advantages the first style can offer for a more basic business structure, such as simplicity of deployment and low costs, weaknesses such as poor scalability and fault tolerance prevent its use in most large production systems today. Researchers in the field of integration architectures discuss the factors that affect the choice between the different models described, depending on the environment and the systems to be integrated. Although the existing literature does not address airports as a case study, they can be compared to other business structures.

The most debated distributed architectures in current research mostly date back to 2005 (Erickson & Siau, 2009) with the emergence of the first service-oriented architectures (SOA), which spread remarkably quickly, replacing some more traditional integration techniques, such as point-to-point architecture. These models allow two applications to be integrated with each other. However, with the exponential growth in the variety of system types and the production needs of large companies, this type of integration has encountered difficulties, including poor scalability and the high cost of adding more connection points (Guan & Barker, 2002).

In turn, existing reflections on service-oriented architectures (SOA) agree that they enable the information technology infrastructure of a company or organisation to be assembled to carry out a series of tasks (Erickson & Siau, 2009; Bieberstein et al., 2005; Niknejad et al., 2020). This type of architecture has made it possible to solve interoperability problems and lay the foundations for distributed applications at Internet scale, as well as to represent a unique model of technological standards for use by software providers (Gorton, 2011). The existing literature points to two main approaches to evaluating an SOA: from business and technological perspectives. Since both perspectives are relevant to the study, we adopt the definition proposed by Niknejad et al. (2020), which describes SOA as an architectural concept that promotes flexible coupling, component reuse, interoperability, agility, and efficiency, with a focus on dividing each business process into smaller functional blocks called services. Services are defined and organised according to a protocol and serve as independent business functionality units that connect with one another to form a unified process (Bieberstein et al., 2005).

In summary, the authors point to numerous advantages of this integration model, highlighting elements such as the ability to scale and manage a variety of operations (Bean, 2010), enhance security, measure performance, easily incorporate new elements of technological innovation (Aires et al., 2025; Boumahdi et al., 2023; Sharma et al., 2024), and support interaction at different levels (Gupta et al., 2016; Niknejad et al., 2020; Marks, 2008). However, advances in technology have enabled the development of new architectural models that aim to address different challenges or objectives. Among these architectures, microservices stand out: they are based on the same principles as SOA but are divided into a larger number of smaller services that can function independently, which, in principle, increases their flexibility (Hustad & Olsen, 2021). Despite representing an advance over traditional service-oriented architectures, it presents some difficulties, such as a greater need for control and a high margin of error (Hustad & Olsen, 2021).

Furthermore, Zimmerman (2016) and Richards (2022) point out that this type of architecture faces several challenges, including data integrity and consistency management, service interface design and evolution, and application security (Matias et al., 2024). When it comes to achieving successful implementation, it is considered one of the most difficult architectures to manage due to the marked granularity of services (Esparza Peidro et al., 2024). This same characteristic poses a challenge to ensuring efficient communication between different services, as well as to managing distributed contract transactions or code reuse (Richards, 2022).

Another architecture that has recently been highlighted in academic work is event-driven architecture. In his studies, Richards (2022) describes this integration model as one based on asynchronous processing using decoupled event processors that activate different sequences and respond to messages produced by the system. The strengths of this type of integration lie in its highly



scalable architecture, high performance, and fault tolerance. Another advantage is its ability to handle complex workflows that are difficult to model (Lazzari & Farias, 2023). At the same time, the authors point out that the weaknesses of this model lie in its incompatibility with organisational structures that perform request-based data processing, for example, knowing a customer's profile. Asynchronous event management is another disadvantage that arises when dealing with a work organisation that requires control over the flows and timing of such events, with service-oriented architectures recommended in these cases (Bukhsh et al., 2015). Finally, it should be noted that when working with problems that require high data consistency, this model is not the most suitable (Richards, 2022). To facilitate understanding of how the different types of architectures work, Table 1 summarises the main characteristics of each one.

Table 1 - Comparative summary of existing integration architecture models

Type of architecture	Description	Advantages	Disadvantages
Point-to-point integration architecture (Hohpe & Woolf, 2003; Guan & Barker, 2002).	In a point-to-point connection, a customised interface is built between two applications, i.e., each system establishes an explicit connection with the other, configured to meet their communication needs. As the number of applications increases, the number of point-to-point connections can increase exponentially.	• Simplicity in initial implementations. • Low cost for limited connections. • Efficiency in direct data transmission.	• Increased complexity as the number of systems grows. • Maintenance difficulties: changes to one system affect multiple connections. • Little flexibility: not suitable for systems that require high interoperability.
Service-oriented architecture (Hustad & Olsen, 2021; Niknejad et al., 2020; Richards, 2022; Gupta et al., 2016; Marks, 2008; Boumahdi et al., 2023).	The main feature of these architectures is the integration of independent applications, called "services," to create an interoperability framework based on a common protocol. A service-oriented architecture is a structural approach to software that improves service delivery in traditional systems without dispensing with their most important components or features.	• Ease of implementation • High adaptability to changes in the environment • Guaranteed use of existing technological and digital resources • Ability to orchestrate processes and services for complex coordination cases • Better customer experience due to data-driven decision-making.	• Complexity of implementation and maintenance in large environments • Existence of a service design-focused approach • Possibility of administrative overload.
Microservices architecture (Richards, 2022; Esparza Peidro, et al., 2024; Matias et al., 2024; Hustad & Olsen, 2021).	The microservices architecture style is an ecosystem made up of single-purpose services, deployed separately, which are normally accessed through an API gateway. Each service accesses its own data or makes requests to other services to access data that the service does not possess. They aim to improve the autonomy, scalability and rapid deployment capacity of services.	• Scalability, flexibility, resilience, and ease of implementation in the cloud • Independent development and updating of services.	• Possibility of management overload due to the number of services and the need for orchestration • Possibility of complications in the management of distributed transactions. • Difficult to apply in cases involving complex companies and tasks.
Event-driven architecture (Richards, 2022; Lazzari & Farias, 2023; Bukhsh et al., 2015).	This is an architectural style based on asynchronous processing using highly decoupled event processors that trigger events and respond accordingly to events occurring in the system.	• Fault tolerance • Good scalability and adaptability to new features • High performance.	• Poor efficiency in controlling flows and execution times • Difficulty in error management due to the asynchronous nature of events.

Source: own elaboration.

In the case study of an organisation with a high level of structural complexity, such as an airport, the selection of the integration model must be based on a series of criteria, including the ability to support different types of services and applications, as well as fault management. That said, the study will be based on the service-oriented architecture (SOA) model, due to the following critical factors that justify this choice:

- It is a model that has been consolidated over time and from a technological perspective (Gorton, 2011).
- It is suitable for large companies (Bieberstein et al., 2005).



- It offers security when managing errors (Boumahdi et al., 2023).
- It is not restricted to a single type of service (Niknejad et al., 2020).
- It solves the problem of combining isolated applications, partial data structures and specific technology platforms (Bean, 2010).

3. Methodology

3.1 Justification of the method

To achieve the objective of designing an integrable architecture, it is necessary to study the feasibility of implementing a model for integrating different airport systems to enable data exchange, synchronisation, and automatic processing, with results that facilitate the management of the airport as a whole. To assess this feasibility, a qualitative methodology is applied, which, by its nature, provides a detailed view of a case or situation from the perspective of the person contributing data or information to the study (Guerrero Bejarano, 2016). Compared with studies based on quantitative criteria, qualitative methodology allows for flexible information gathering, simpler adaptation of the data collection procedure, and the avoidance of misunderstandings among interviewees, among other aspects (Storey, 2007).

One of the procedures frequently used in qualitative research is the study of people's opinions on a specific topic, based on personal interviews or questionnaires. Some of the most commonly used methods that address this approach are the Delphi method and the snowball method. The Delphi method is a research support tool used to obtain a detailed view of a specific topic, based on the opinions of experts in a field (Ramírez & Ramírez, 2024). It allows different perspectives to be explored and conclusions to be drawn based on a consensus of ideas (Rowe & Wright, 2001). Achieving consensus in this method is the key element, although there are differing reflections in the existing literature on how to define this phenomenon within the framework of the method (von der Gracht, 2012).

In turn, the snowball method is traditionally applied in small study groups, such as groups of specific experts, to obtain useful information and constitutes intentional sampling (Ritchie & Lewis, 2006). Unlike the Delphi method, it does not seek to obtain consensus but rather focuses on gathering a wider range of details that help to construct a vision of the aspect of interest for the research. The final group of experts to be interviewed will depend on the participants themselves, as the first people interviewed help to identify the next ones (Ritchie & Lewis, 2006). Traditionally, there is no minimum number of interactions with experts; rather, the data collection cycle stops when new interviewees no longer provide new or relevant information. In this research, the snowball method will be applied due to its ability to provide information to the study while respecting different perspectives. It is worth noting that there are other studies in a similar field. For example, Korkmaz et al. (2023) used the snowball method among a group of experts at Istanbul's Ataturk Airport to identify the main causes affecting airport security.

3.2 Justification of the case study and initial selection of experts

According to Air Traffic Statistics from Spanish Airports and Air Navigation (AENA, 2025), in 2024, Malaga-Costa del Sol Airport handled 174,919 operations, serving almost 25 million passengers. These figures position the infrastructure in question as the fourth most important nationally and the third most important airport on the Spanish part of the peninsula. In turn, the initial selection of experts to be interviewed was based on their position within the airport structure, with the first to be selected being those in senior management at the airport in question. The interviews were then extended to management representatives from specific departments, who were recommended by the first experts who participated in the study, in line with the selected method's theory. In this way, the feasibility of implementing an interoperable system is studied from the perspective of the different departments that make up the airport itself. As a result of the procedure applied, three representatives from the management department, three from the operations department, two from the commercial department, one expert from the airport services department, and, finally, one representative from the customer service area participated.

3.3 Data collection

Firstly, according to the selected method's theory, two pilot interviews were conducted with senior managers at Malaga-Costa del Sol Airport to identify priorities, needs, and areas of interest for future interviews, and initial contacts were requested from individuals to begin the study. Secondly, to ensure data integrity and facilitate subsequent analysis, a structured interview approach was followed, based on a series of questions organised into the thematic blocks listed in Table 2:

**Table 2 - Interview structure**

Name of the block	Objective	Number of questions
1) Experience with current systems	Identify the degree of efficiency of current systems and their limitations	4
2) Opinion on technological integration	Assess experts' perceptions of the proposal for a single, interoperable system	5
3) Prediction and personalisation of services	Assess the usefulness of the proposal for data-based personalisation	3
4) Feasibility and adoption of the proposal	Assess perceptions of the feasibility of implementing the integrated system	3

Source: own elaboration.

At the beginning of each question block, respondents were asked to rate their level of agreement with the main idea of the block on a scale of 1 to 5, as follows:

- 1) The current systems you work with are well integrated with other airport departments.
- 2) The integration of the aforementioned systems would facilitate passenger flow management.
- 3) Greater knowledge of passenger profiles and behaviour could be used to improve their experience.
- 4) This type of system could be implemented at the airport without negatively affecting daily operations.

A total of 10 interviews were conducted, in addition to the initial two pilot interviews. It should be noted that 27 interview requests were initially distributed, and obtaining a representative number of responses was considered a significant challenge for the study. The representativeness of the responses determined the final number of interviews, and it was found that from interview number 7 onwards, the responses were in line with the reflections previously provided by other experts. The interview cycle was completed to consolidate the results.

3.4 Data analysis

Mayring's method, traditionally considered very useful for structured and semi-structured qualitative analyses (Mayring, 2000), was used to analyse the data. The method is based on predefined categories that, in this case, coincide with the sections of the pre-designed interview structure. To proceed with the next stage of analysis, which consists of coding fragments, the responses were first transcribed in summary form and recorded in a Google Forms document created for this study with exclusive access for the authors. This format facilitates the visualisation and detection of the main ideas, as well as quick comparisons between responses.

Next, to code and process the information entered into Forms, MAXQDA software was used to define thematic categories and to associate different codes with text fragments to measure their frequency of appearance in the interviews. In this study, the categories correspond to the four blocks of defined questions, and each question within a block corresponds to a subcategory. Next, labels/codes were assigned to each relevant fragment of the responses obtained. The graphs that visually present the study's results show the key ideas from the questions on the horizontal axis, while the tags generated in MAXQDA are shown on the vertical axis. Between the two, the intensity of each interviewee's opinion or idea regarding the question can be identified. Subsequent data validation was carried out through the member-checking procedure, in which the interviewees themselves corroborated the summarised results.

4. Results

4.1 Results by thematic blocks

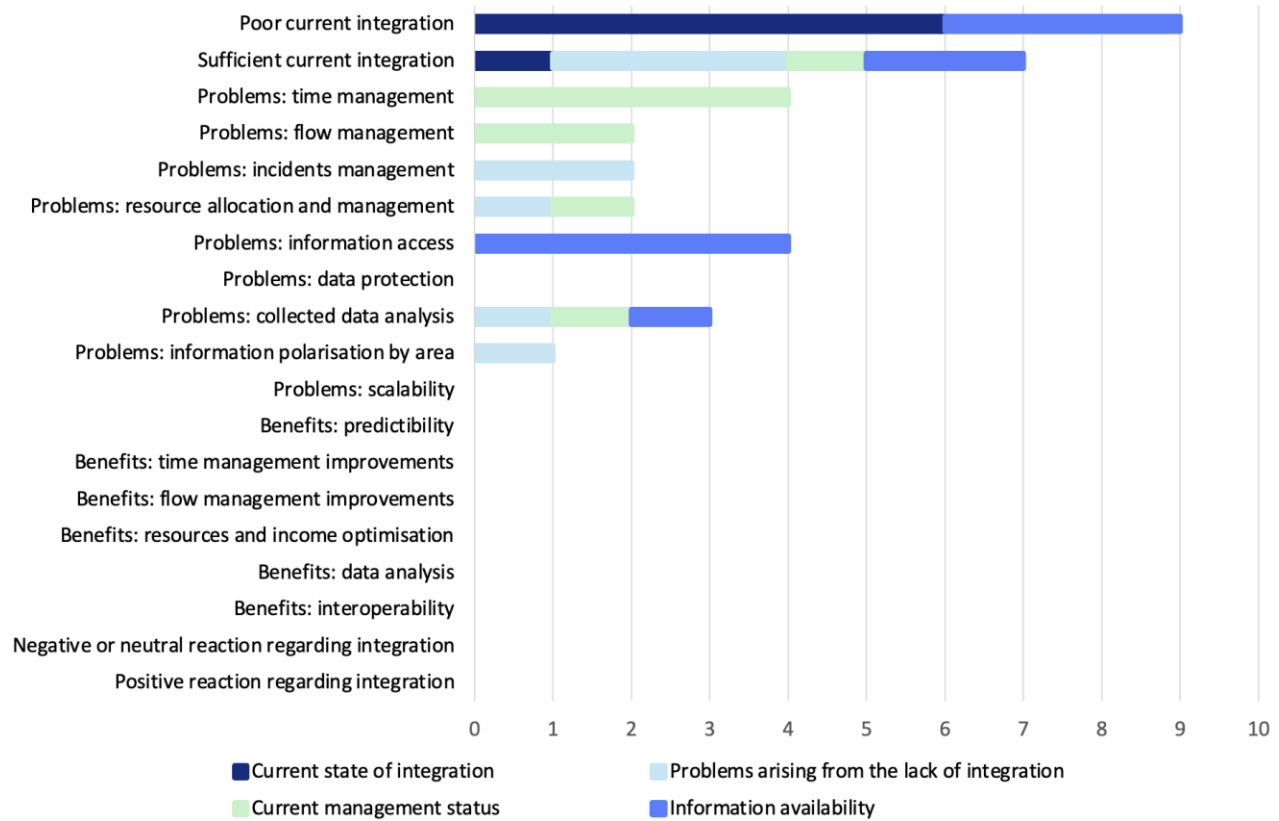
4.1.1 Experience with current systems

As shown in Figure 1, the overall assessment indicates that the current level of integration is quite limited and has possibilities for improvement. Among the main difficulties currently highlighted by the lack of integration between systems is that the information available on passengers is grouped by operational areas, which increases the risk of delays in responding to incidents and entails additional day-to-day workload and analysis. The interviewees agree that the main difficulty they currently face in flow management is the waiting times at the various controls (passport, security) and services such as VIP lounges and baggage



collection. They also point out that although a large amount of passenger information is currently available across different areas, the current mechanism does not facilitate exchange and analysis between departments. Therefore, it could be further optimised if more detailed information were available from the beginning of the passenger's itinerary and the flight in question.

Figure 1 - List of codes in response to the questions in block 1



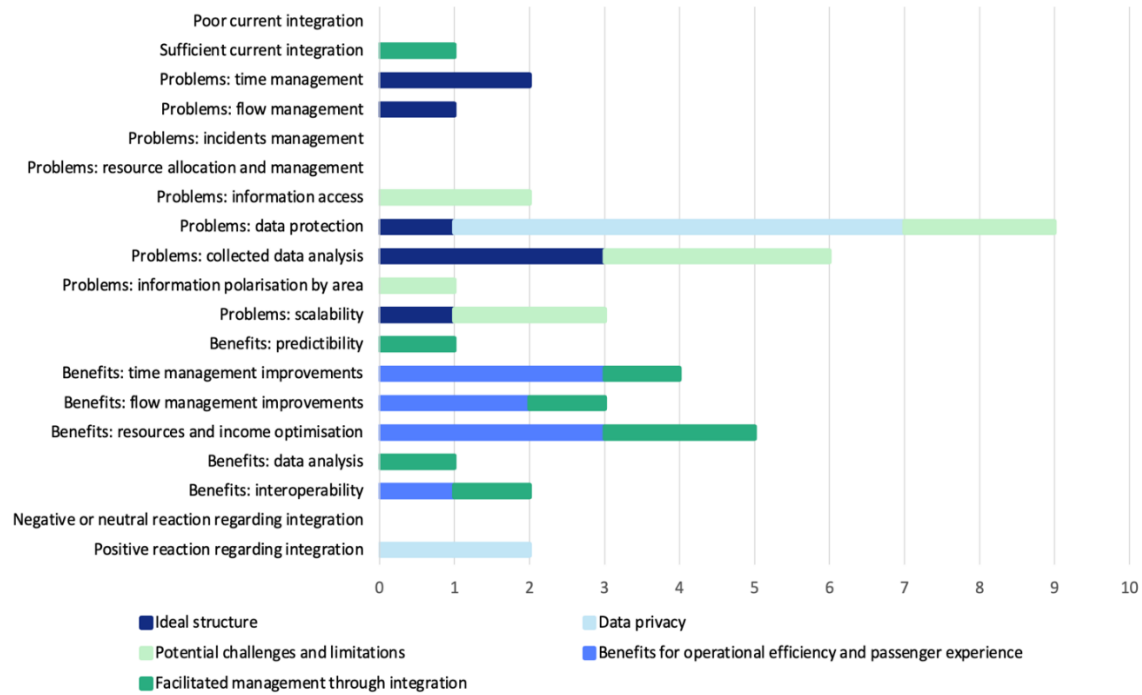
Source: own elaboration.

4.1.2 Opinion on technological integration

The interviewees agree that full integration of operating systems at the airport would facilitate data analysis and decision-making, the configuration of predictive systems and time planning – key aspects highlighted by researchers of innovation models at airports. Other factors mentioned as benefits of this integrated architecture include the optimisation of commercial revenue, incident resolution, and resource planning by providing an overview of the entire structure in real time. One of the challenges to be highlighted when implementing an interoperable system effectively is the proper management of personal data, in line with current cybersecurity policies that already govern the performance of certain operations in an interoperable manner. In this regard, the anonymisation of data and its exclusive and confidential internal use within the AENA network must be guaranteed. In general terms, as shown in Figure 2, the essential characteristics and elements for implementing a technologically integrated system include the ability to adapt the system to airport changes, machine learning capabilities, and security throughout the process.



Figure 2 - List of codes in response to the questions in block 2

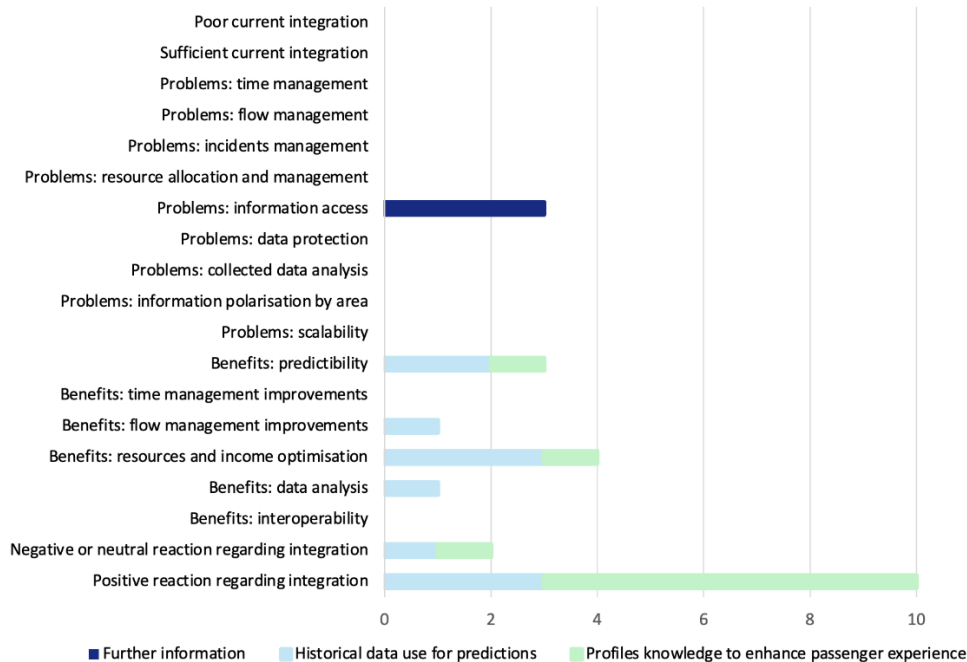


Source: own elaboration.

4.1.3 Prediction and personalisation of services

Most experts agree that greater knowledge of passenger profiles can be used to improve the passenger experience at airports. However, they suggest taking into account certain biases inherent to departments regarding schedules and labour regulations, which is why the scope for optimising this experience is considered limited (Figure 3). The use of historical and real-time data is also highlighted as a fundamental element in their departments for, among other things, establishing patterns, improving resource planning, estimating demand, optimising resources, and, consequently, the quality of service. A system of this nature could be used to identify the areas of highest passenger traffic at the airport and the length of stay, an element that has not been addressed to date.

Figure 3 - List of codes in response to the questions in block 3



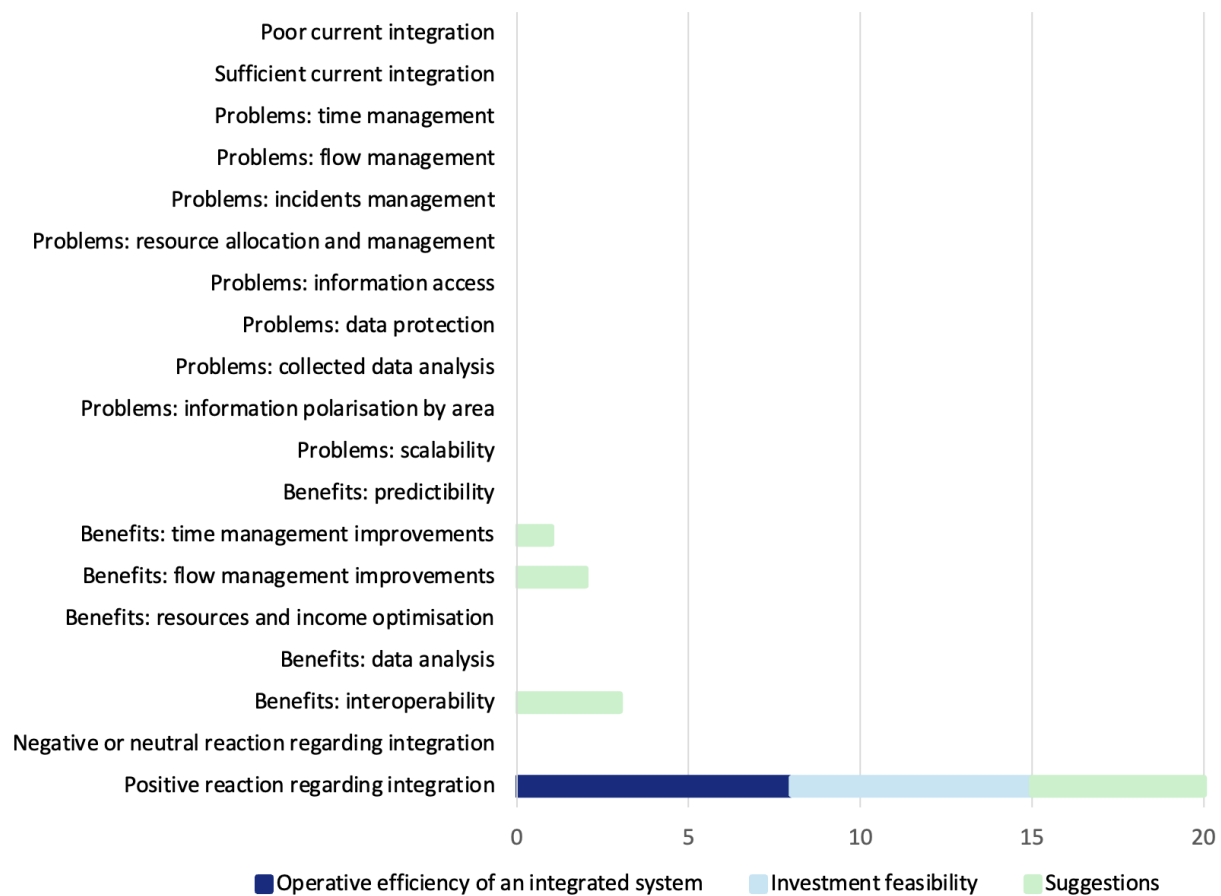
Source: own elaboration



4.1.4 Feasibility and adoption of the proposal

Finally, as shown in Figure 4, there was complete consensus among the experts interviewed when asked about the likelihood that such a system would contribute to a systematic improvement in the relationship between the airport and passengers. In fact, they share the view that this technological investment would be profitable. However, they also emphasise the importance of considering the airport's size and capacity, as a small airport with lower passenger flow may have limitations. When asked to provide free suggestions for the design of an integrated system of this type, the experts mentioned the clear definition of the system's quality and performance indicators (KPIs) to be able to measure the results adequately; the scalability and integration of processes in a sequential manner; and the inclusion of the different stakeholders that make up the destination where the airport structure is located.

Figure 4 - List of codes in response to the questions in block 4



Source: own elaboration.

4.2 Proposed model

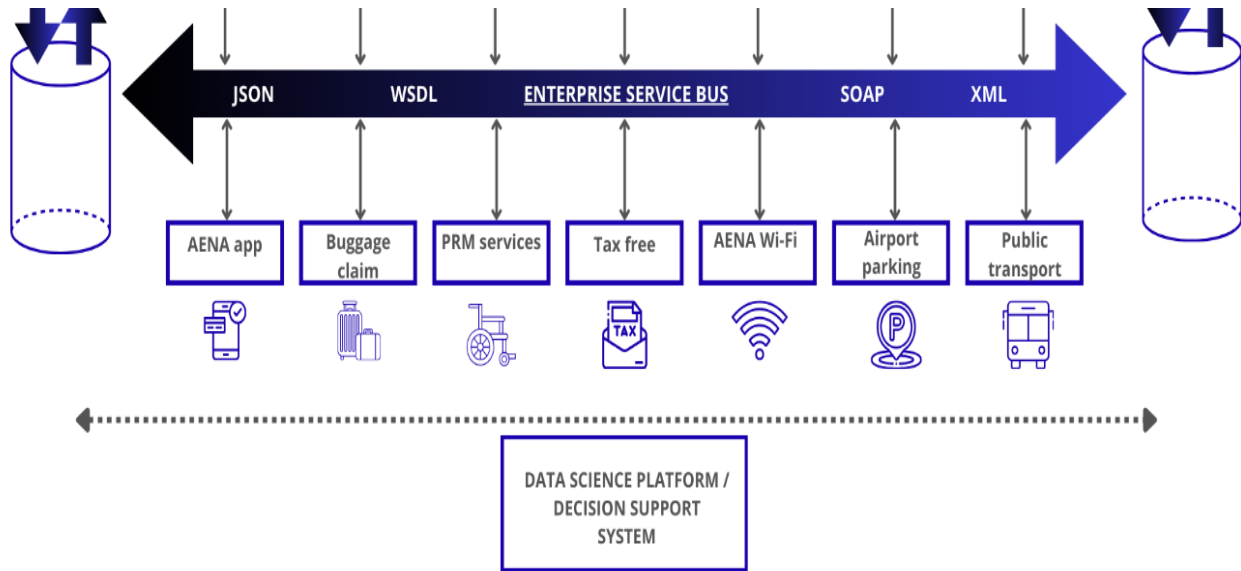
Based on the responses collected during the interviews, a technological architecture model has been formulated that, in a simplified way, reflects the flow that an integrated system of this type must follow (Figure 5). To ensure the representativeness of the proposed flow, the steps and definitions proposed by Solarte-Martínez et al. (2021) were followed, where the essential element of an SOA-type integrated system is undoubtedly the existence of middleware (enterprise service bus) that centralises and directs queries to the different subsystems of the organisation at the same time, simultaneously receiving the responses for subsequent processing. In our study, all systems that make up the airport structure, as identified during the interviews, are included. Specifically, there are a total of 14 internal and external subsystems that interact with the aforementioned middleware, receiving queries and returning responses. Information is traditionally exchanged in JSON, WSDL, SOAP or XML format. The flow of messages is based on the data stored in their corresponding databases and can be structured or unstructured (text, numbers, time records, images, etc.).

The proposed technology architecture model (Figure 5) is based on the various considerations identified during the research phase through interviews. Specifically, the core of the system addresses views expressed about the current state of the system (section



4.1.1), thereby synchronising data flows across different systems and preventing, for example, the polarisation of information by area, whilst ensuring universal access and information availability. The data science or decision support module, in turn, facilitates the analysis and integrity of information (4.1.2 and 4.1.3), providing strategic insights to address various challenges, including time and flow management, resource optimisation, and predictability. The aforementioned analysis module, which integrates different systems and data types, ensures not only the integrity of the information but also its interoperability, with the core system ensuring real-time information exchange and traceability.

Figure 5 - Graphical representation of the integrated architecture model applied to the airport



Source: own elaboration.

The implementation of such an integrated system would mean greater personalisation of the service for tourists and passengers throughout their journey through the airport. A simple example of how this mechanism works is the exchange of data between AENA's web and mobile applications, different control systems (security, customs, passports, etc.), commercial and operations management services (e.g., baggage), and even the airlines themselves. With a comprehensive dashboard displaying all passenger data and their interactions with different controls and resources offered by the airport in real time or based on historical activity, airport managers can obtain information on travel time between stages; complete passenger profiles based on flight history, purchases made in the app or on site; link certain destinations to a specific traveller profile; condition travel times and the distribution of resources at the airport, among other issues.

5. Discussion

The innovative aspect of the study, due to its subject matter and the combination of the technological integration procedure between systems applied to the operational and business model of an airport structure, has yielded results that corroborate the problems detected by other authors in their various manifestations, as well as generating additional knowledge in areas that remain underexplored. Firstly, the results align with the hypotheses formulated by authors Von der Burg and Sharpanskyh (2025), highlighting the significant need to automate and align processes across different airport blocks to support efficient decision-making and enable comprehensive, detailed predictions of activity within the airport.

Specifically, the interviews highlighted the importance of integrating existing systems within the airport itself, as well as recommended a series of integrations with external systems at the tourist destination level to optimise the business model and offer passengers a personalised, seamless experience during their stay at the airport facilities. The capacity to make predictions through access to real-time interdepartmental information, in addition to historical data, has been highlighted with particular interest, as it is an area of action that directly affects the intelligence of the processes carried out.

Secondly, the results corroborate the ideas described in the studies by Nayeem et al. (2025) and Scala et al. (2021), which highlight the importance of establishing efficient interaction among different airport departments to understand the sequences of events



and the reasons behind them. Although the aforementioned authors relied on simulation and process modelling, this research, by establishing the feasibility of creating a system with an integrated architecture across the different departments, makes a significant contribution to previous studies. Thus, the availability of an integrated system can facilitate such simulations by providing established relationships and both current and historical data.

Other relevant studies in the field of passengers and their interactions with airports rely on studies of their feelings or observation of their activities to establish behaviour patterns (Alanazi et al., 2024) that can be used by airport agents to adapt services and improve performance; or they address systems integration with a primary focus on the airport's own internal processes, i.e., weather forecasting, runway process efficiency, or automated scheduling (Dalmau et al., 2025; Roling & Viser, 2008; Schultz et al., 2021). The results show that these approaches to the study, both those relating exclusively to passengers and those relating to operational processes at airports, have a place in the approach proposed in this research paper, as integrated architecture provides a solution that delivers results for different objectives and departments, where improving the efficiency of airport processes themselves and their relationship with passenger satisfaction are considered important.

Regarding the proposed architecture model, the ideas expressed by the experts surveyed coincide with the results collected in the studies by Vernadat (2003) and Grant and Yeo (2021), stating that technologically integrable management models offer significant advantages to the organisations that use them, providing flexibility, ease of incorporating new processes and components, knowledge of the structure's activity at all times and the application of new strategies in the minimum time necessary – aspects highlighted as particularly relevant for large structures. As already mentioned in the theoretical framework, recent studies have not combined the application of integrated architectures as a solution and response to the need for information and process synchronisation in large structures such as airports. However, due to the efficiency of SOA architectures discussed in numerous studies (Hustad & Olsen, 2021; Niknejad et al., 2020; Richards, 2022, etc.), a practical model proposal has been developed that responds both to the challenges at the airport level and to the technological trends that guarantee the desired outcome for the organisation.

6. Conclusions

The main objective of this research is to design an integrated technological architecture for the systems that interact with passengers before and during their time at the airport, based on a feasibility study carried out with industry experts. As a result of the study carried out, this work provides a theoretical and practical validation of an innovative mechanism for integrating the airport's operating systems, establishing a procedure for interoperability and the traceability of passenger activities throughout their journey. The validated proposal provides a knowledge base for future developments in real airport system environments and contributes to more intelligent management processes.

6.1 Theoretical Implications

This article presents a proposal for a high-level, integrable technological architecture for airport systems, based on knowledge from a series of previous studies and qualitative research through interviews, which have revealed the distinct needs and characteristics of airport infrastructure. The selected research approach represents an important contribution to the existing academic literature due to its innovative nature, as scientific work in the field of airports has so far barely examined the potential of technological integration to improve the performance of a structure of this size, as well as its implications for the passenger experience. At the same time, it corroborates various aspects highlighted in recent scientific studies on the relevant factors that determine the success of today's airports, such as predictive capabilities, data analysis and real-time response capabilities, process automation and dynamic interaction between departments to improve the service provided to travellers, in addition to knowledge of their profile.

6.2 Practical Implications

From a practical perspective, it has been found that the current technological system at one of the most important Spanish airports has room for improvement, as there is functional isolation among the current systems. Therefore, the results also provide valuable insights for managers in the Spanish airport system. The research has shown that technological integration between systems has the potential to solve many existing problems that have been highlighted during the interviews, including data fragmentation and its concentration in specific departments, which makes it difficult to obtain a comprehensive understanding of passenger profiles, a lack of information to manage people flows efficiently, and a lack of a joint data vision to make predictions, among others. The main result is the experts' unanimity on the usefulness of an integrated technological system for improving the passenger experience and internal processes at the airport. To meet these needs and requirements expressed during the interviews, a model was designed and represented in diagrams that summarise the flow of processes and tasks in a system with multiple databases or



management systems. A common query management module stands out as an essential element to facilitate subsequent data processing – a key aspect in a service-oriented architecture, considered the most appropriate among those researched to date.

6.3 Limitations

One of the most challenging aspects of the research has been contacting experts in the airport sector, due to their busy schedules. In this regard, although the procedure followed was snowball sampling and the contacts provided by the experts interviewed in advance were a great help, feedback was not guaranteed. Therefore, on several occasions, it was necessary to return to the previous set of respondents to obtain alternative contacts for agents they considered relevant for inclusion in the research work. Consequently, the risk of over-representation of certain professional areas has been a significant challenge. Due to low response and feedback rates from certain agents or departments, some responses have been concentrated in specific departments. As a result, responses have been received from representatives of five different departments, which constitute a representative sample, as these departments have greater interaction with passengers. However, the inclusion of a wider range of specialisations has been limited by the aforementioned response rate.

6.4. Suggestions for future research

A possible future line of research for this initial study could combine a wider range of methods, introducing quantitative aspects, as well as testing or modelling based on advanced technologies such as machine learning. In this regard, different passenger behaviour scenarios could be developed based on the airport's decisions, using data from an integrated system, and dwell times could be predicted using software equipped with artificial intelligence, among other things. The possibilities mentioned in the discussion section regarding the combination of simulation and modelling methods with an integrated architecture represent another important aspect, both from the perspective of the academic viability of the subject matter and for consolidating the practical implications.

To this end, an important aspect for subsequent research would be access to real data provided by the airport itself, which would enable modelling of data exchange integration between different systems, simulation of scenarios based on this data, and prediction generation. In line with the limitations described, it is considered important for subsequent studies to include a greater number of operational areas of the airport to enhance the robustness of the practical procedures for modelling the architecture and conducting subsequent simulations.

Credit author statement

All authors have contributed equally. All authors have read and agreed to the published version of the manuscript.

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