Smart and Sustainable Built Environment

Smart airports as responsive systems: a systematic literature review and network analysis

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Abstract

Purpose – Research on smart airports is expanding but remains fragmented across architecture, operations, passenger experience, technology and sustainability. This paper synthesises that evidence and reframes smart airports as socio-technical systems in which "smartness" emerges through cross-domain interaction rather than standalone technologies.

Design/methodology/approach – A Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA)-aligned systematic literature review is integrated with network analysis of 511 peer-reviewed articles published between 2019 and 2024. The review synthesises 433 unique sub-indicators spanning infrastructure and spatial design, operational efficiency, passenger experience, enabling technologies and sustainability. Net-work analysis maps relationships among sub-indicators to identify structural dependencies and cross-domain clustering.

Findings – Operational efficiency constitutes the backbone of smart airport systems, while architectural adaptability is associated with the translation of operational intelligence into physical action Passenger experience is shaped primarily by seamless flow, information continuity and perceived control rather than discrete amenities. Technology operates as a transversal enabler connecting domains, whereas sustainability is unevenly embedded and more often treated as an outcome of efficiency-led initiatives than as an integrated design logic. The most consequential opportunities and tensions concentrate at the interfaces between architecture, operations and passenger experience.

Research limitations/implications – The review is restricted to English-language publications and a deliberately narrow 2019–2024 window, which may under-represent earlier foundational work and non-English regional evidence. The network approach uses recorded linkage as a proxy for relationship strength, and the reported centrality measures do not weight relationships by valence.

Practical implications – The results support airport planners and operators in moving beyond gadget-centric initiatives by highlighting where integration typically fails: aligning architectural flexibility, cross-functional coordination and governance with operational and passenger-facing digital systems. The study provides a reference point for assessing organisational and infrastructural readiness for digital transition.

Originality/value – By combining a PRISMA-guided review with sub-indicator network analysis, this paper provides an evidence-based map of interdependencies to inform integrated planning and governance of adaptive, passenger-centred airport environments.

Keywords Smart airports, Systematic literature review, Network analysis, Operational efficiency, Passenger experience, Architectural adaptability, Sustainability

Paper type Research article

1. Introduction

1.1 Smart airports as evolving socio-technical systems

The global aviation sector is undergoing a structural shift shaped by rapid digitalisation and escalating climate obligations (Gürsel *et al.*, 2023; Gößling, 2020). Airports are increasingly

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framed as adaptive, data-driven infrastructures rather than static transport infrastructures (Şahin and Durmaz, 2023; Molchanova, 2020). In this framing, the smart airport is positioned as a cyber-physical ecosystem where sensing, analytics, and automation influence both operational performance and human-centred services (Lykou *et al.*, 2019; Svitek *et al.*, 2021). This shift extends beyond upgrading discrete technologies. It redefines the airport as an environment that can respond to changing demand, risk conditions, and resource constraints through continuous feedback (Safaeianpour and Shamandi, 2022). In parallel, decarbonisation pressures are reshaping how airports justify growth, measure performance, and prioritise efficiency interventions (Jia *et al.*, 2023; Di Vaio and Varriale, 2020). These developments increasingly position airports as interconnected environments in which physical infrastructure, digital systems, and organisational processes operate in combination rather than independently.

However, the scholarly landscape documenting this transformation remains dispersed across disciplinary and sectoral silos. Studies addressing architecture, operations, digital infrastructure, sustainability, and passenger experience are frequently developed in isolation from one another, limiting understanding of how these systems interact within the broader transformation of airport environments.

1.2 Fragmented evidence and the cross-domain gap

Research on smart airport transformation remains spread across disciplines. Built-environment studies commonly privilege terminal performance, energy demand, and environmental modelling, which can leave digital systems treated as enabling utilities rather than central components of airport design and operation (Ramakrishnan *et al.*, 2023; Keskin, 2021). Operational scholarship, by contrast, tends to foreground data-driven optimisation and automation, often abstracted from the spatial and material conditions that shape how these systems perform in practice (Amiri and Kuşakcı, 2024; Kovynyov and Mikut, 2019). Passenger-focused work frequently emphasises satisfaction, trust, and behavioural adoption, yet this can compress the airport experience into a linear service sequence rather than a situated encounter shaped by governance, risk protocols, and infrastructural constraints (Batouei *et al.*, 2020; Ma *et al.*, 2022a). Each strand of research provides valuable insights, but the separation between them makes it difficult to examine airport transformation as an integrated process.

Earlier studies have nonetheless begun to examine smart airports through more integrated perspectives. Conceptual reviews of digital transformation in aviation describe airports as environments in which multiple layers of infrastructure and digital systems operate together (Şahin and Durmaz, 2023; Alansari *et al.*, 2019; Svitek *et al.*, 2021). Studies examining Industry 4.0 technologies in airports have similarly documented the breadth of digital initiatives currently under development while recognising that their effectiveness depends on coordination across stakeholders and operational systems (Tan and Masood, 2021). Cybersecurity-oriented research has likewise framed the airport as a connected environment whose reliability is shaped by interactions between sensing, control, and governance layers (Lykou *et al.*, 2019; Samuri *et al.*, 2023).

More recent built-environment research has begun to formalise cross-domain analysis, mapping shared influencing factors across otherwise separate planning domains (Reja *et al.*, 2026) and proposing layered frameworks that couple regulatory and digital systems in smart city settings (Choorapulakkal and Fadli, 2026). Comparable network-based bibliometric approaches have also been applied to digital transformation research in the built environment (Schery *et al.*, 2025). Within airports, however, recent network-based analysis has remained focused on individual subsystems, such as airfield lighting, rather than on architecture, operational efficiency, and passenger experience considered together (Naung *et al.*, 2026). Whereas these reviews synthesise the smart airport literature thematically or bibliometrically at the level of studies and research themes, the present review codes the literature into sub-

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indicators and their documented relationships, allowing cross-domain dependencies to be examined directly rather than inferred from thematic grouping.

Research Gap: Existing smart airport research has largely examined architecture, operations, and passenger experience separately, with limited attention given to how these systems influence airport transformation when considered together. While previous studies have discussed airports as integrated or socio-technical environments, limited attention has been given to systematically examining the relationships between architectural, operational, and passenger-focused systems within smart airport development.

Addressing this gap matters because decisions shaping smart airport transformation rarely occur within a single domain. Passenger-facing technologies depend on operational coordination, operational systems influence spatial planning, and sustainability outcomes are shaped by both organisational and infrastructural arrangements. Without a clearer understanding of these relationships, existing research offers limited support for integrated planning and decision-making across airport environments.

1.3 Research aim, objectives, and questions

Against this background, the paper aims to examine how architecture, operational efficiency, and passenger experience interact within smart airport transformation through a structured review of the existing literature. Two objectives follow from this aim. The first is to identify the factors influencing smart airport transformation across these three domains, drawing on how they are discussed within the peer-reviewed literature. The second is to examine how these factors interrelate, with particular attention to the cross-domain linkages shaping transformation in both newly developed and transitioning airport environments.

In line with these objectives, the study is guided by the following research questions:

(1) What are the key factors influencing smart airport transformation within the domains of architecture, operational efficiency, and passenger experience?

(2) How do factors across architecture, operational efficiency, and passenger experience interrelate to shape the transformation of new and transitioning airport environments?

The three analytical domains correspond to the principal components of a socio-technical system, with architecture representing its technical and material layer, operational efficiency its organisational processes, and passenger experience its human dimension; the coded sub-indicators record how each of these components is discussed within the reviewed literature (Geels, 2004; Hughes, 1987).

Sustainability is treated in this study as a transversal outcome influenced by interactions across the three analytical domains rather than as a separate fourth domain, while governance represents the institutional conditions through which these interactions are coordinated. The following sections outline the review design and analytical approach adopted to address these questions before presenting the synthesis of the reviewed literature.

2. Methods

2.1 Review design and rationale

This study adopts a Systematic Literature Review (SLR) to investigate the dispersed knowledge base of smart airports (Page *et al.*, 2021; PRISMA Statement, 2025). An SLR over a traditional narrative review for its transparency and reproducibility (Samarasekara *et al.*, 2024). This approach provides a reproducible synthesis of existing evidence rather than relying on anecdotal observation. The review was structured in accordance with the PRISMA 2020 guidelines to support transparency and consistency during study selection. Adhering to this protocol ensures the resulting conceptual framework is grounded in verifiable empirical data. We tailored the design to the inherently cross-disciplinary nature of smart airport research. It spans diverse fields, including engineering, architecture, computer science,

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information systems, and management (Ghaffarianhoseini *et al.*, 2017a). We treat the literature as a dynamic network of interrelated concepts rather than a fixed catalogue.

2.2 Search strategy and data sources

A multi-layered search strategy was developed to capture the breadth of the smart airport discourse. Peer-reviewed journal articles and conference proceedings were targeted to balance conceptual scholarship with implementation-oriented evidence. The search used Scopus as the primary bibliographic database, complemented by ScienceDirect as a publisher-hosted full-text discovery platform and Google Scholar as a supplementary interdisciplinary discovery source.

These search sources were selected for their broad and complementary coverage of disciplines relevant to airport development and digital transformation (Mongeon and Paul-Hus, 2016). Carefully structured keywords and Boolean operators were employed to maximise retrieval breadth while maintaining relevance. Core search terms focused on the central phenomenon, principally "smart airport" and "smart airports". Google Scholar's dynamic indexing and relevance-ranking processes can limit the reproducibility of search results. This limitation was managed by recording the complete query structures and source-level search dates reported in the Supplementary Material, applying consistent eligibility criteria, and subsequently deduplicating retrieved records against the other search sources. Searches were executed between 14 June and 10 July 2024, and a total of 16,056 records constituted the formal search output used for the documented screening workflow. Table 1 reports source-level retrieval totals.

The Supplementary Material reports the complete search strings, search dates and retrieval totals for Scopus, ScienceDirect and Google Scholar.

2.3 Eligibility criteria and screening process

We managed the retrieved volume through a multi-stage screening process using predefined criteria. Eligibility rules were established in advance of screening to maintain objectivity throughout the review. A detailed summary of these inclusion and exclusion rules is provided in Table 2.

The screening followed a funnel logic consistent with PRISMA 2020 guidelines. First, duplicates were identified and removed using JabRef to detect overlapping titles. Second, titles and abstracts were screened for relevance to smart airport transformation. This step filtered out metaphorical or tangential uses of airport language effectively. Third, full texts of candidate papers were retrieved and assessed against eligibility rules. We confirmed substantive alignment rather than relying on superficial keyword matching. Study-selection counts were verified against the original screening and consolidation records. Exclusions at the title and abstract stage reflect relevance screening rather than retrieval failure; all reports sought for retrieval were obtained. Figure 1 reports the corrected progression from identification through

Table 1. Summary of search sources and retrieval totals

Database	Number of search strings	Total number of hits
Scopus	44	3,760
ScienceDirect	47	4,338
Google Scholar	27	7,958

Source(s): Authors' own work

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Table 2. Eligibility criteria

Inclusion	Exclusion
Peer-reviewed studies on smart airports (2019–2024) focusing on infrastructure, operational efficiency, passenger experience, sustainability, and the implementation of smart technologies	Studies published before 2019, those unrelated to airport settings or lacking relevance to operational efficiency, passenger experience, or sustainability
Comparative research on traditional versus smart airport design across regions and types, along with empirical studies, case studies, and insights into smart airport practices, is available in English	Theoretical papers, editorials, opinion pieces, and research without substantial empirical data are excluded. Studies without comparative or contextual relevance and non-English publications without accessible full text or English abstracts

Source(s): Authors' own work

relevance screening and final eligibility assessment, with source-specific counts reconciled to the final corpus of 511 studies.

2.4 Data management and advanced coding strategy

Data management followed a structured workflow using JabRef and Microsoft Excel. JabRef served as the bibliographic store and supported systematic duplicate removal. Excel was used for screening logs, tracking decisions, and organising the corpus. This separation kept the audit trail clear during early eligibility filtering. After screening, the analytical workflow moved from manual coding to a hybrid approach. MAXQDA 24 housed full texts and supported initial code assignment. It also preserved links between extracted segments and coded sub-indicators. The integrated storage and analysis workflow is summarised in Figure 2.

To extend the analysis beyond exact keyword matching, semantic similarity was incorporated into the coding process using the all-MiniLM-L6-v2 Sentence-Transformer model. The analytical unit was the text passage associated with a candidate sub-indicator, and cosine similarity was used to identify passages semantically related to the evolving thematic structure. The model functioned as a candidate-retrieval aid rather than as an automatic coding classifier; no fixed similarity threshold was applied, and consequently no candidate was accepted solely on the basis of similarity score. Each flagged passage was manually reviewed against its surrounding context and retained only where the text substantively represented the intended sub-indicator; superficial lexical matches, unrelated contextual uses and ambiguous references were rejected.

Coding followed a hybrid inductive–deductive process across open, axial and selective coding stages, as illustrated in Figure 3. The primary researcher acted as the principal coder, while the four-member supervisory team participated in the review and validation of the coding structure. Candidate codes were checked against their originating text, and ambiguous or overlapping classifications were discussed with the supervisory team and resolved through consensus, consistent with negotiated-agreement approaches to qualitative coding (O'Connor and Joffe, 2020). The coding process initially produced 434 sub-indicators; during final consolidation, one duplicate entry was identified and removed before network construction, yielding 433 unique sub-indicators for subsequent analysis. A formal intercoder-reliability coefficient was not calculated because coding was undertaken by a primary coder rather than through independent parallel coding. Quality control instead relied on source-text verification, supervisory review and consensus-based resolution of ambiguous classifications.

2.5 Sub-indicator matrices and network analysis

To move beyond frequency-based analysis, network analysis was used to examine the structural organisation of relationships among the identified sub-indicators (Newman, 2010;

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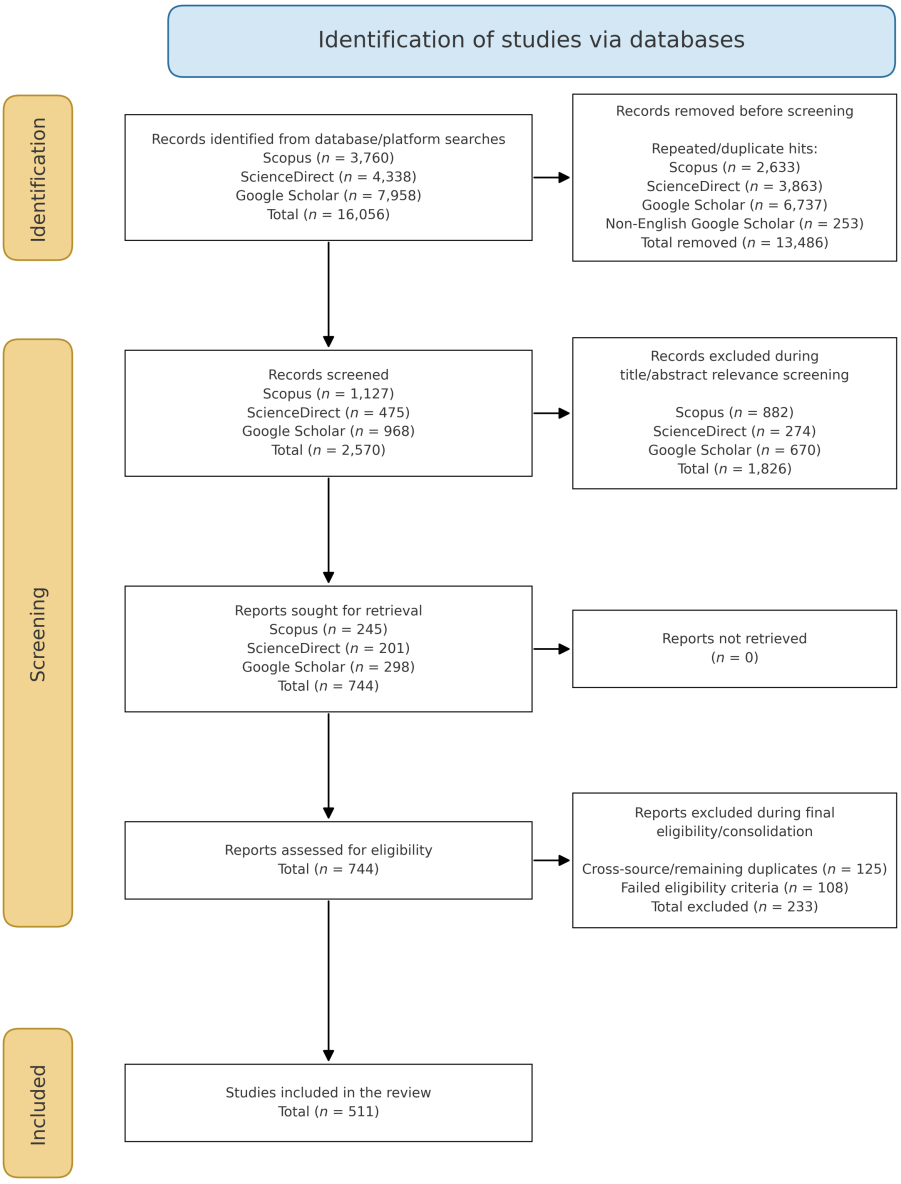


Figure 1. PRISMA 2020 flow diagram showing the identification, screening, eligibility assessment and final inclusion of 511 studies in the systematic literature review. Source: Authors' own work, adapted from Page *et al.* (2021)

Borgatti *et al.*, 2018; Ghaffarianhoseini *et al.*, 2017b). Coded outputs were transformed into two complementary matrices for subsequent network construction and analysis in Gephi. The first, termed the Document–Sub-indicator Matrix, recorded the presence of each sub-indicator within each study as a binary value. Sub-indicators populated the columns and document identifiers populated the rows. A binary entry was recorded only where the source text

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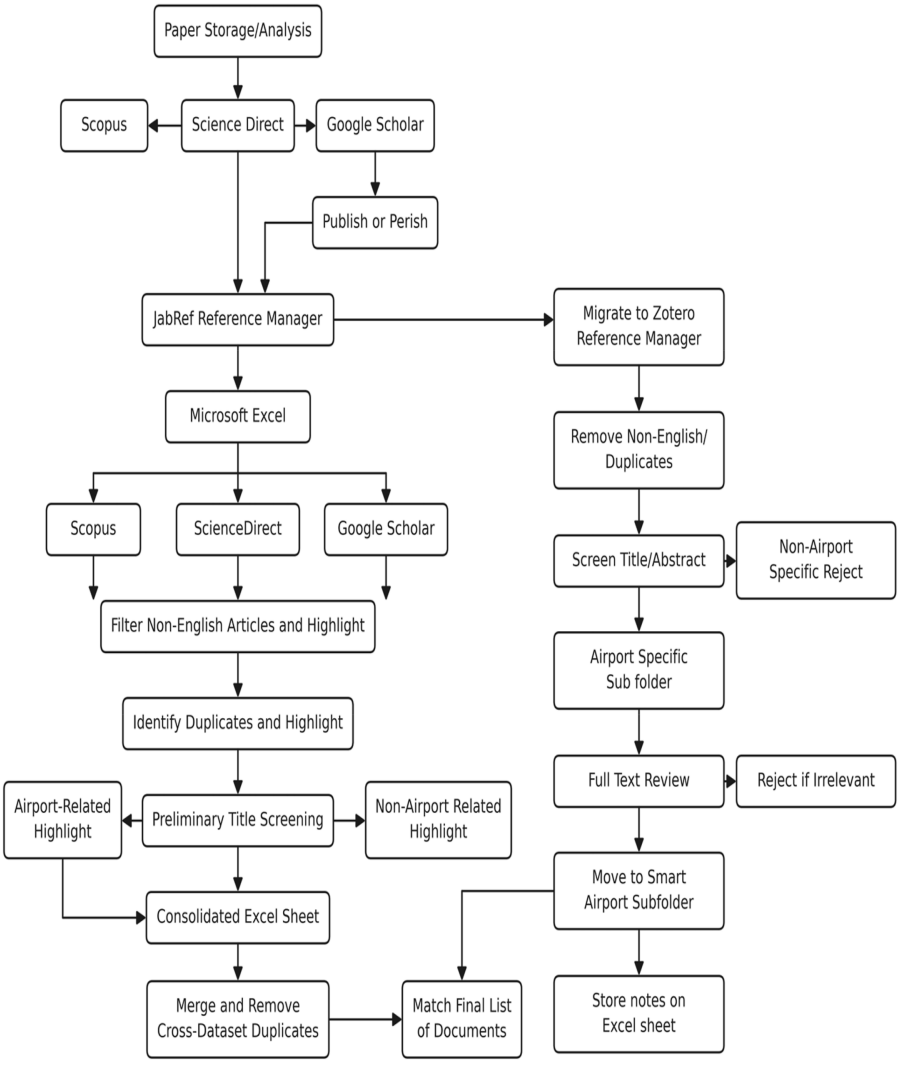


Figure 2. Systematic Literature Review (SLR) paper storage and analysis workflow. Source: Authors' own work

explicitly supported the corresponding sub-indicator, and each entry was cross-checked against the originating document. This matrix provided the document-level occurrence structure used to examine frequency and co-occurrence patterns. Table 3 summarises the construction protocol.

The Document–Sub-indicator Matrix was also used to examine cross-domain co-occurrence and semantic overlap among the 433 unique sub-indicators. This analysis was used descriptively to identify areas of stronger thematic convergence and comparatively weak overlap across the analytical domains. Because the analysis was intended to characterise patterns of association within the reviewed literature rather than estimate causal relationships, these cross-domain patterns were interpreted alongside the network results rather than as independent statistical effects.

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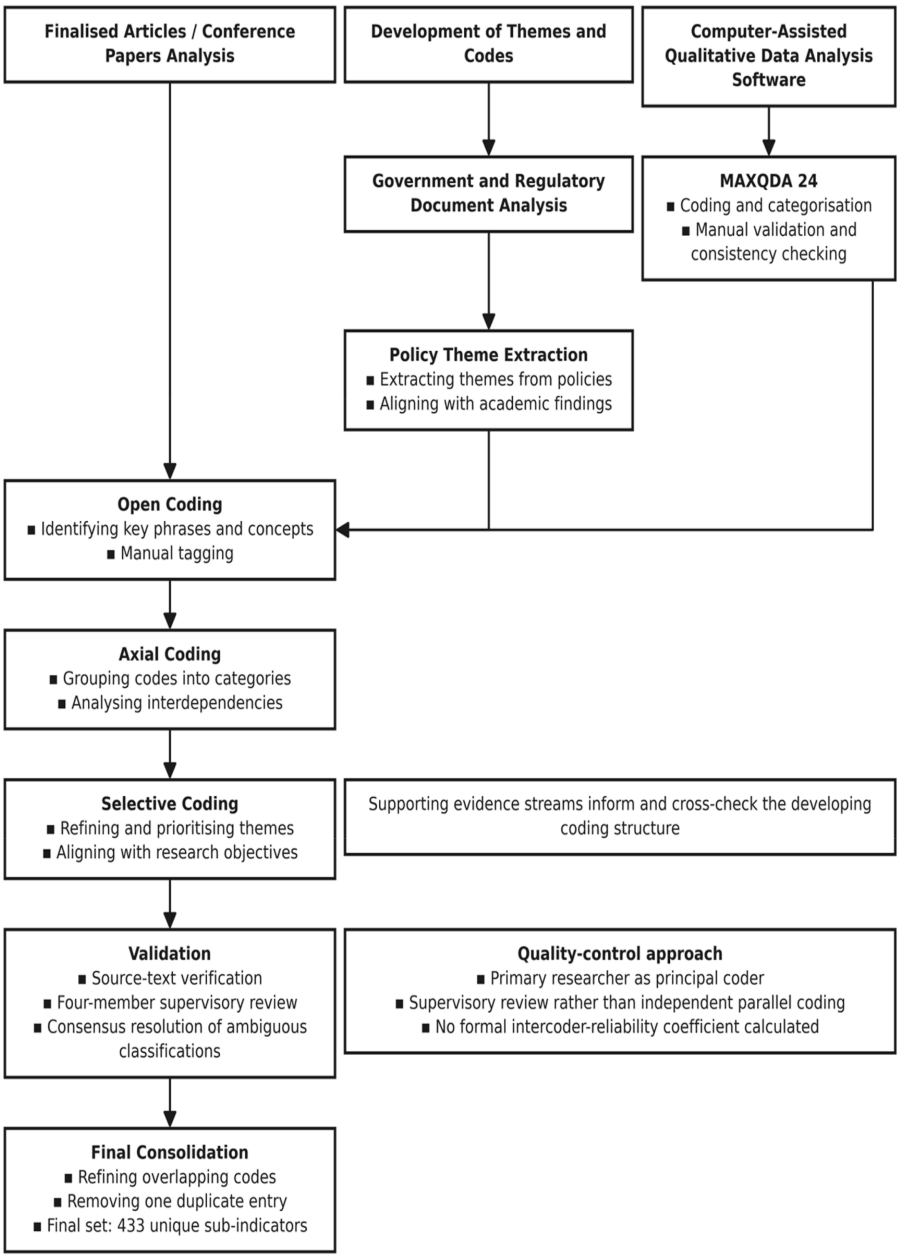


Figure 3. Coding, validation and consolidation process used to develop the final sub-indicator set. Source: Authors' own work

The second matrix, termed the Sub-indicator Relationship Matrix, captured explicit conceptual or operational relationships between sub-indicators. A relationship was recorded only where the source text explicitly linked two sub-indicators as interacting, interdependent

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Table 3. Document-sub-indicator matrix methodology

Steps	Actions	Purpose and rationale
Matrix Setup	Sub-indicators (e.g. "AI and Machine Learning") were listed across the top row, and document identifiers were listed down the first column	To establish a structured, centralised repository for organising extracted data variables
Data Input	A binary entry (✓) was recorded only if the source text explicitly discussed the sub-indicator in an operational context	To systematically quantify the presence of sub-indicators based on strict textual evidence rather than implication
Cross-Checking	Each entry was manually verified against the original source text to confirm contextual fit	To ensure data reliability and eliminate false positives derived from keyword occurrence
Handling Missing Data	Non-standard terminology was mapped to the nearest equivalent sub-indicator using a standardised semantic dictionary	To ensure comprehensive data capture that accounts for semantic variation without misrepresenting author intent
Synthesis and Analysis	The completed matrix was aggregated to identify document-levelfrequency and co-occurrencepatterns	To quantify how frequently sub-indicators occurred across documents and provided a basis for examining patterns of co-occurrence

Source(s): Authors' own work

or occurring within the same operational process. Each coded relationship retained the source and target sub-indicator, the supporting document citation and, where explicitly supported by the text, its directional polarity. Multiple documents supporting the same source–target relationship were retained as repeated evidence, allowing the frequency of supporting documents to represent the strength of documentary support for that relationship. The coding, verification and export procedure is summarised in Table 4.

The relationship data were subsequently imported into Gephi for directed network construction and structural analysis. Nodes represented the 433 unique sub-indicators, while directed edges represented explicit source–target relationships identified in the reviewed literature. Relationship polarity was retained in the exported data, with positive and negative relationships distinguished by their coded sign. Where multiple documents supported the same source–target relationship, these documentary instances were retained as separate evidence edges rather than collapsed into a single relationship, thereby preserving the frequency of support within the network. Directional connectivity was retained during analysis through separate in-degree and out-degree measures, alongside total degree, betweenness centrality, eigenvector centrality, clustering coefficient and eccentricity. ForceAtlas2 spatialisation was used for network visualisation to reveal structural clustering through simulated attraction and repulsion. Relationship polarity was retained in the coded relationship data and visualisations, but the reported centrality measures were interpreted as indicators of structural position and connectivity rather than as measures of the desirability or causal strength of individual relationships.

(1) *Degree Centrality vs Frequency:* While simple frequency counts reflect the popularity of a topic, degree centrality measures connectivity. A discrepancy between low frequency and high centrality identifies "hidden structural nodes"—concepts that are rarely the primary focus of a study but are essential for connecting distinct operational domains.

(2) *Betweenness centrality* identified bridging indicators that connect otherwise separated thematic communities (Freeman, 1977).

(3) *Eigenvector centrality* signalled influence by weighting connections to other influential nodes.

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Table 4. Sub-indicator relationship matrix and network visualisation methodology

Steps	Actions	Purpose and rationale
Matrix Setup	Sub-indicators were represented as potential source-target pairs within the relationship matrix	To provide a structured representation of explicitly identified relationships among sub-indicators
Data Input and Coding	A relationship was recorded only where the reviewed text explicitly linked two sub-indicators. Source and target codes, supporting citation(s), and relationship polarity were retained where supported by the source	To preserve the evidential basis, direction and interpreted nature of each coded relationship
Verification	Each relationship was cross-checked against the originating document. Repeated support for the same relationship was retained separate evidence records	To verify contextual accuracy and quantify repeated documentary support for individual relationships
Qualitative Analysis	The complete matrix was analysed to identify frequently cited relationships, thematic clusters, and potential gaps in the existing research	To derive qualitative insights about the structure of the scholarly conversation and identify key areas of interaction within the framework
Data Export and Visualisation	The matrix data was exported into a compatible format and imported into Gephi for network analysis	To move beyond a static table and visually represent the complex web of interconnections in a more intuitive manner
Network Interpretation	Gephi's analytics were used as structural sub-indicators to support qualitative interpretation	To identify central themes, influence pathways, and systemic interdependencies

Source(s): Authors' own work

(4) *Clustering coefficient* assessed local cohesion by measuring the interconnection among a node's neighbours.

(5) *Eccentricity* captured reach by indicating the longest shortest-path distance from a node. Network layouts and metric outputs are reported in the Results section, not here.

Accordingly, the centrality measures are interpreted as indicators of structural prominence and connectivity within the reviewed literature network rather than as evidence of causal influence between sub-indicators.

3. Results and discussion: the integrated smart airport ecosystem

The systematic review and network analysis demonstrate that smart airport transformation cannot be explained through isolated domain-level optimisation alone. Architectural intelligence, operational efficiency, and passenger experience each display distinct structural characteristics within the network; however, the strongest patterns consistently emerge through their interactions rather than within individual subsystems. The findings indicate that airport transformation is shaped through relationships between physical space, digital systems, and passenger-facing processes rather than through any single technological layer. This supports the interpretation of smart airports as integrated socio-technical systems rather than collections of discrete technologies (Geels, 2004; Hughes, 1987). Such system-oriented perspectives have been operationalised in built environment research through structured cross-domain synthesis and interaction-based analysis (Ghaffarianhoseini *et al.*, 2017a, b).

This perspective challenges assumptions within parts of the literature where innovation is often framed primarily through the adoption of advanced technologies. Instead, the results

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suggest that system performance depends on how effectively architectural, operational, and passenger-focused systems function together. As observed in the cross-domain analysis, these interdependencies generate both synergies and operational tensions, particularly across the architecture–operations, operations–experience, and architecture–experience interfaces. Consequently, similar technologies may produce different outcomes depending on how effectively they are integrated within the airport environment.

3.1 Corpus characteristics publication trends and volume

The final corpus comprises 511 studies, showing sustained growth in academic interest in smart airports. Annual output rose from 12 studies in 2019 to 69 in 2020, 108 in 2021, 121 in 2022 and 129 in 2023, with a further 67 dated to 2024 at the point of retrieval in mid-2024. This pattern suggests a shift from specialised technical studies towards broader aviation strategy and operational planning. Output remains highest across 2021–2023. This concentration aligns with the industry's COVID-19 response and its emphasis on contactless operations. During this period, studies focused more on health monitoring and operational resilience. The timing suggests that digital transformation has increasingly shifted from efficiency enhancement towards operational resilience. These trends establish the context for the theme-frequency results reported next. The values reported in Table 5 represent aggregated matches to the synthesised sub-indicators assigned to each analytical domain, rather than literal occurrences of the domain labels themselves. Sub-indicator expressions may comprise single words or multi-word phrases; for example, terms such as "IoT devices", "real-time information systems" or "comfortable seating" were counted under their corresponding coded sub-indicators and subsequently aggregated at domain level.

These values are therefore interpreted as descriptive indicators of the volume of coded sub-indicator references within the reviewed corpus. Because annual totals are influenced by both the number and length of documents published in a given year, raw year-to-year counts are not treated as normalised measures of thematic intensity. Dictionary-based theme-frequency analysis supports this shift, with contactless and health codes appearing across the post-2020 literature. Table 5 summarises these year-by-year totals. Coded references to operational themes consistently exceed those to architectural themes in every year of the review period. This imbalance indicates uneven development across the smart airport ecosystem. It points to reactive adaptation, where digital layers were integrated under crisis pressure. Incremental spatial optimisation appears secondary in the same period. The results, therefore, suggest that smart airport adoption during this period was driven not only by technological development but also by the operational pressures created by the pandemic.

3.1.1 Geographic and sectoral distribution. Geographically, the literature is global yet unevenly distributed. The Asia–Pacific region—particularly China and Singapore—dominates the discourse on digital-native greenfield delivery. In these contexts, smart features are embedded at the design stage rather than treated as add-ons. By contrast, European

Table 5. Dictionary-based thematic frequency by year (2019–2024)

Year	Architecture	Operational efficiency	Passenger experience
2019	13,880	38,563	14,893
2020	68,304	188,144	66,627
2021	118,955	322,186	115,064
2022	121,994	345,110	125,279
2023	111,795	311,142	112,323
2024	73,635	212,391	76,176

Source(s): Authors' own work

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and North American studies concentrate on responsive retrofit transformation, integrating digital layers into constrained brownfield layouts and legacy spatial configurations. As detailed in Table 6, this divergence highlights how operational performance in legacy environments remains tightly bound to spatial constraints.

3.1.2 Domain coverage overview. Across the corpus, research attention is unevenly distributed across the three core analytical domains. Operational Efficiency is the most frequently represented domain, reflecting sustained emphasis on throughput, safety and process optimisation, while technology appears extensively as an enabling layer across studies. Passenger Experience also receives increasing attention in the more recent literature, particularly in relation to service quality, health assurance and passenger confidence. Table 7 further illustrates this distribution through aggregate sub-indicator match frequencies, representing the total number of accepted lexical and semantic matches associated with the synthesised sub-indicators within each analytical domain. These totals represent matches to the underlying sub-indicator terminology and associated variants, rather than literal occurrences of the domain labels themselves. Architecture records 520,859 accepted matches and Operational Efficiency records 1,449,074; these values are interpreted descriptively and are not treated as normalised measures of thematic intensity because they are influenced by document number, document length and the number of sub-indicators represented within each domain.

3.1.3 Complete network characteristics. The complete directed network comprised 433 unique sub-indicator nodes and 2,627 literature-supported directed relationship records. Based on the directed graph, network density was 0.014, indicating that approximately 1.4% of all theoretically possible directed connections were represented in the reviewed evidence. Component analysis identified 121 weakly connected components and 204 strongly connected

Table 6. Geographic and sectoral distribution of smart airport development

Pathway	Focus and findings	Supporting documents and connection
Digital-Native Greenfield Delivery	***Focus:*** Asia–Pacific (e.g. China, Singapore). Large greenfield investments ***Finding:*** Smart features are embedded at the design stage	**(Siddiqui and Mead, 2024):** Digital Twin as a platform for Master Planning. (Highlights planning for digital-native design) **(Mohammed *et al.*, 2021):** Emergence of secondary airports to resolve capacity limits
Responsive Retrofit Transformation	***Focus:*** Europe and North America. Constrained brownfield sites ***Finding:*** Operational performance is tightly bound to spatial constraints	**(Zhang *et al.*, 2022):** Multi-Objective Optimisation of Gate Assignments. Connects efficiency to fixed constraints **(Gelhausen *et al.*, 2021):** Mitigation strategies for Capacity Constraints **(Suriyanarayanan *et al.*, 2022):** Dynamic provisioning of resources to handle uncertainty

Source(s): Authors' own work

Table 7. Aggregate lexical and semanticsub-indicator matches by analytical domain

Domain	Total frequency
Operational Efficiency	1,449,074
Passenger Experience	521,390
Architecture	520,859

Source(s): Authors' own work

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components; the largest weakly connected component contained 311 nodes. Modularity analysis partitioned the network into 137 communities, reflecting a large connected core alongside a substantial number of smaller or peripheral clusters. The aggregated node and edge data underlying these measures are available from the corresponding author on reasonable request.

3.2 Architecture: network structure and system integration

Architecture as an Integrated System: In smart airport environments, architecture is increasingly shaped by the integration of sensing, data, and control systems rather than by static physical form alone (Qian *et al.*, 2022; Remencová and Sedláčková, 2021). Terminals, therefore, function not only as physical infrastructures but also as environments that support operational coordination, environmental monitoring, and passenger-facing services (Safaeianpour and Shamandi, 2022; Samha *et al.*, 2020). Consistent with smart airport life-cycle approaches, capabilities such as digital integration, data continuity, and model-based coordination increasingly operate as embedded architectural functions rather than isolated technological additions (Svitek *et al.*, 2021; Tan and Masood, 2021). The prominence of technology-oriented sub-indicators within the network therefore suggests that architectural performance is increasingly linked to system integration across operational and digital layers.

Across the SLR period, dictionary-based theme frequencies show steady growth in digitally enabled architectural indicators, suggesting gradual, cumulative capability-building rather than short-term, post-event acceleration (Siddiqui and Mead, 2024). This mirrors industry reporting on multi-year transformation programmes in data platforms, cyber resilience, automation, and passenger-enabling systems (Tan and Masood, 2021; Samha *et al.*, 2020). This is consistent with peer-reviewed frameworks that emphasise the maturation of connectivity, interoperability, and governance over time (Samuri *et al.*, 2023; Mijuskovic *et al.*, 2020). These patterns suggest that architectural performance increasingly depends on long-term integration between digital systems, operational coordination, and infrastructure management (Ghaffarianhoseini *et al.*, 2017a). This supports reproducibility by tying claims to long-term patterns within a defined corpus.

Figure 4 network of the top ten architectural sub-indicators further shows an interdependent feedback structure linking sensing inputs, analytics and spatial/service outputs (Ma *et al.*, 2024a; Zhou *et al.*, 2023). Data moves through platform and processing layers into adaptive terminal behaviours, reflecting documented airport data-platform transitions and the importance of continuity, model integration and decision-latency management (Siddiqui, 2019; Ma *et al.*, 2022b). SLR coding reinforces that these indicators are typically discussed in co-occurrence with technology enablement, operational coordination and risk governance, not in isolation (Lykou *et al.*, 2019; Qian *et al.*, 2022).

Network metrics isolate ten architectural sub-indicators with disproportionate structural influence as shown in Table 8. Beyond term frequency, they act as integrators that connect otherwise separate clusters, stabilising the architecture domain by enabling cross-domain coordination. Degree and eigenvector scores separate visibility from embedded influence, while betweenness identifies which concepts carry bridging load across the network. In smart-airport research, that bridging load is typically borne by platform-level concepts that unify heterogeneous devices, stakeholders and processes within shared information environments (Siddiqui and Mead, 2024; Zhang *et al.*, 2023). Their recurrence across modelling, empirical and conceptual studies indicates a reproducible feature of the 2019–2024 corpus rather than a single-method artefact. The ten sub-indicators reported for each analytical domain in Tables 8–10 were selected by ranking the domain-specific nodes according to the cumulative network score reported in the tables. This score combines the reported degree, eigenvector centrality, betweenness centrality, eccentricity and clustering-coefficient values and was used to identify nodes exhibiting the strongest overall structural prominence within each domain. The ranking therefore reflects network position rather than document frequency alone.

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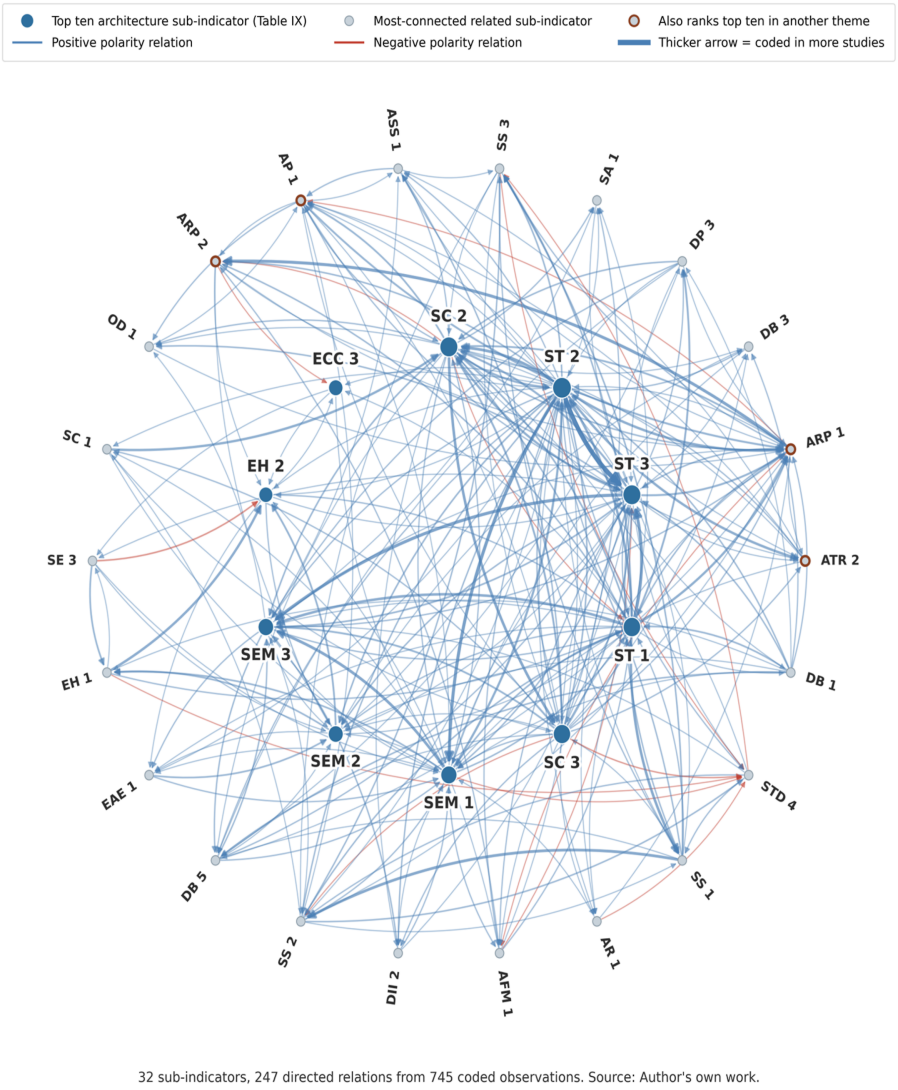


Figure 4. Network analysis of top 10 sub-indicators: architecture. Note the high centrality of digital nodes (ST 2, SC 2) compared to physical nodes, illustrating that the "digital spine" of terminals is more structurally prominent within the reviewed literature than static building components. Sub-indicator codes are defined in Table 8

3.2.1 Interpretation of key architecture sub-indicators. SC2 Real-time Information Systems ranks prominently because it provides the communication spine through which architectural information can be connected with operational and passenger-facing functions High betweenness indicates that it occupies a bridging position between sensing, operational coordination and passenger information services (Zhang *et al.*, 2020; Yuan and Jiang, 2023). This aligns with airport shifts towards unified data platforms, where real-time exchange underpins resilience and responsiveness. Architecturally, "responsiveness" depends less on isolated smart components than on continuous, available and governed information flows;

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Table 8. Architecture: top ten sub indicators by network metrics

Rank	Code	Sub-indicator	Degree	Eigenvector	Betweenness	Eccentricity	Clustering	Cumulative	Author
1	SC 2	Real time information systems	0.6832	0.553638	8829.49	5	0	8835.72	139
2	ST 2	Integration of IoT devices	1.0000	0.372310	8830.98	0	0.358820	8832.71	183
3	ST 3	Real time data processing and analytics	0.8549	1.000000	7707.69	5	0.378588	7714.92	212
4	ST 1	AI and machine learning	0.6870	0.238106	7544.42	0	0	7545.34	160
5	SC 3	Mobile and web based communication	0.4618	0.310575	6800.08	5	0	6805.85	81
6	SEM 1	Sensors and IoT devices	0.4503	0.370066	4053.92	0	0	4054.74	126
7	SEM 2	Energy management systems	0.2213	0.195250	3577.71	0	0	3578.12	75
8	SEM 3	Data analytics	0.4351	0.843488	3298.43	5	0.388080	3305.09	123
9	EH 2	Energy efficiency	0	0	2490.47	0	0	2490.47	57
10	ECC 3	Carbon offsetting programmes	0	0	1504.02	0	0	1504.02	63

Source(s): Authors' own work

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Table 9. Operational efficiency: top ten sub-indicators by network metrics

Rank	Code	Sub-indicator	Degree	Eigenvector	Betweenness	Eccentricity	Clustering	Cumulative	Author
1	ARP 1	Operational Efficiency	1	0.55245	16287.28	5	0.157653	16293.99	91
2	ARC 2	Customer Experience Enhancement	0.2952	0.1745	5692.74	6	0.161176	5699.37	28
3	AP 1	Queue Management Services	0.4095	0.216584	3665.50	5	0.25441	3671.38	79
4	OK 1	Passenger Wait Times	0.4048	0.227922	2671.76	6	0.181507	2678.57	55
5	OT 3	User Satisfaction Rating w/New Tech	0.1238	0.059192	2464.54	6	0.094862	2470.82	8
6	ER 1	Runway Capacity	0.0810	0.034186	2415.37	6	0.042857	2421.52	17
7	EE 1	Energy Consumption	0.2952	0.109124	2151.38	6	0.141147	2157.92	50
8	ARP 2	Cost Savings	0.2667	0.336594	2102.19	5	0.287707	2108.08	52
9	ATR 2	Baggage Tracking System	0.2429	0.184296	1849.04	6	0.25641	1855.73	48
10	ED 3	Resource Allocation	0.2000	0.12449	1591.58	6	0.149733	1598.06	42

Source(s): Authors' own work

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Table 10. Passenger experience: top ten sub-indicators (network metrics)

Rank	Code	Sub-indicator	Degree	Eigenvector	Betweenness	Eccentricity	Clustering	Cumulative	Author
1	HC 4	Air filtration systems	0.8148	0.018100	854.57	6	0.084211	861.48	39
2	EAD 2	Mobile app integration	0.3333	0.001377	697.38	6	0.069444	703.78	8
3	ACA 2	Baggage Handling Automation	0.8519	0.030650	696.63	6	0.183333	703.69	16
4	PC 1	Real-Time Flight Updates	0.2222	0.001633	576.67	6	0.133333	583.03	9
5	LD 1	Online Catalogue	0.4074	0.008491	575.61	6	0.177778	582.20	2
6	LS 2	Comfortable Seating	0.1481	0.000268	538.40	7	0.083333	545.63	4
7	LS 3	Amenities	1.0000	0.067147	530.07	6	0.257246	537.39	7
8	SBA 1	Types of biometrics used	0.5556	0.028158	372.14	5	0.233333	377.95	16
9	SCP 3	Security Measures Implemented	0.7778	0.053025	339.46	6	0.180952	346.47	17
10	EV 4	Integration with real-time flight information	0.1852	0.020877	294.94	6	0.166667	301.32	5

Source(s): Authors' own work

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low-latency approaches (e.g. fog-enabled architectures) are repeatedly positioned as enablers because they reduce delay between sensing and control (Siddiqui, 2019; Mijuskovic *et al.*, 2020).

ST2 Integration of IoT Devices ranks highest in degree centrality, indicating that it is the most densely connected infrastructural layer within the Architecture network. The density reflects that architectural intelligence relies on pervasive instrumentation, embedded systems and interoperable interfaces (Qian *et al.*, 2022; Santamaria *et al.*, 2019). The same connectivity also expands the attack surface, so IoT integration has direct consequences for reliability and resilience within cybersecurity and risk-governance research (Lykou *et al.*, 2019; Ukwandu *et al.*, 2022). The literature's persistent focus on device heterogeneity, lifecycle management, and security controls frames IoT integration as a sustained lifecycle obligation—from procurement to decommissioning—rather than a one-off deployment (Malhotra *et al.*, 2021; Qian *et al.*, 2022). This helps explain its strong bridging role across multiple operational and technological functions.

ST3 Real-time Data Processing and Analytics emerges as a structurally prominent interpretive node, associated with the conversion of sensor outputs into information used for environmental control, flow management and passenger guidance (Ma *et al.*, 2024a; Valarmathy *et al.*, 2023). Its eigenvector prominence indicates close coupling to other influential nodes: analytics amplifies connectivity and information systems rather than substituting for them (Yuan and Jiang, 2023; Zhang *et al.*, 2023). In asset and lifecycle discussions, analytics is increasingly tied to model-based integration (e.g. BIM/digital twins) that provides a semantic backbone for interpreting operational data within spatial systems (Siddiqui and Mead, 2024; Lunacek *et al.*, 2021). Case studies position analytics as a process involving shared architectures and governance models, rather than as standalone tools (Moghadasnian, 2024; Malhotra *et al.*, 2021). This indicates that architectural systems increasingly rely on coordinated data processing rather than isolated sensing functions.

ST1 AI and Machine Learning appears as a higher-order capability associated with extending architectural intelligence from reactive control towards predictive/adaptive optimisation (Vonitsanos *et al.*, 2021; Ma *et al.*, 2024a). Its network role is more bridging than clustering because AI is applied across loosely coupled functions (screening, maintenance, personalisation), often with uneven integration across organisational boundaries (Mäkelä, 2024; Zhang *et al.*, 2023). Across the corpus, AI's architectural impact is typically conditional on mature IoT instrumentation and data platforms—enhancing, rather than replacing, underlying integration capacity.

SC3 Mobile and Web-Based Communication plays a strategically important interface role, linking system intelligence to passenger-initiated interactions. Its contribution is primarily translational: converting system awareness into usable signals (wayfinding, disruption messaging, self-service prompts) (Wongyai *et al.*, 2024; Zhu *et al.*, 2023). Evidence from self-service technology reviews positions mobile/web channels as foundational for adoption of digital services (check-in, e-ticketing, automated touchpoints), while industry trend reporting identifies passenger-enabling digital channels as sustained areas of investment attention (Wongyai *et al.*, 2024; Tan and Masood, 2021). Its weaker clustering is therefore coherent: interface functions connect many domains without forming a tight internal architectural cluster.

Environmental intelligence is distributed across *SEM1–SEM3*, which together form the sensing, optimisation and feedback substrate of architectural adaptability (Ma *et al.*, 2024a; Tang *et al.*, 2023a, b). Sensors/IoT provide the input layer, analytics interprets signals into decision logic, and energy/management systems are associated with translating interpreted information into performance-oriented actions for resource optimisation and operational continuity (Ma *et al.*, 2024a; Zoutendijk and Mitici, 2024). Cybersecurity research views these sensor networks as critical infrastructure because failures can spread across interconnected systems. This necessitates reliability controls, resilience planning, and ongoing lifecycle governance rather than just a one-time installation (Lykou *et al.*, 2019; Samuri *et al.*, 2023).

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Collectively, these nodes position architecture within the reviewed literature as a responsive cyber-physical layer rather than a static envelope.

Finally, *EH2 Energy Efficiency* and *ECC3 Carbon Offsetting Programmes* enter the top tier mainly through bridging roles: they connect architectural intelligence to sustainability governance and reporting discourse more than to dense real-time control integration (Wennberg, 2019; Ramakrishnan *et al.*, 2022). Energy performance is often viewed as a measurable and benchmarkable outcome within structured evaluation frameworks. In contrast, decarbonisation pathways are typically discussed at the system level, encompassing supply, storage, and optimisation, and can surpass the boundaries of terminal architecture (Sreenath *et al.*, 2021; Zeng *et al.*, 2024). Carbon initiatives, in disclosure-oriented work, remain closely tied to organisational practices and reporting structures, and can therefore be loosely coupled to real-time control mechanisms (Wennberg, 2019; Ramakrishnan *et al.*, 2022). The network pattern suggests that sustainability connects these strands of the literature, although it is not yet consistently represented as an integrated architectural control logic within smart-airport research.

3.2.2 Synthesis of architectural network insights. The architectural network shows that smart-airport design is shaped by coordinated system relationships rather than isolated technologies. Highly connected nodes support coordination across the domain, while bridging nodes link the architecture to operational systems, technology, and the passenger experience. Architectural performance increasingly depends on the coordination of sensing systems, real-time information exchange, analytics, and governance processes (Ma *et al.*, 2024a; Zhou *et al.*, 2023). No single sub-indicator is sufficient on its own, as capabilities such as AI and digital interfaces depend on the maturity of underlying data platforms and IoT infrastructure (Mäkelä, 2024; Zhang *et al.*, 2023). Similar patterns have also been identified in other complex built-environment systems examined through systematic synthesis, supporting the consistency of these findings beyond the airport context (Samarasekara *et al.*, 2024). Sustainability indicators appear less embedded within real-time control systems and are more commonly linked to evaluation and reporting functions, positioning environmental performance more as a strategic outcome than as a consistently operational architectural mechanism (Wennberg, 2019; Ramakrishnan *et al.*, 2022). Overall, the findings suggest that architectural effectiveness in smart airports depends less on isolated technologies and more on how digital, operational, and spatial systems function together.

The architecture–operations interface emerges as a critical zone in smart airport transformation. Operational systems increasingly rely on real-time data, automation, and predictive analytics for decision-making. Their effectiveness, however, remains tightly bound by the physical characteristics of the built environment. Architecture, therefore, functions as both an enabler and a constraint on operational responsiveness. It shapes how digital intelligence can be translated into spatial and material action. The results, specifically the high betweenness of ST 2 and SC 3, indicate that operational optimisation is inseparable from architectural adaptability. Without spatial flexibility, digital capability remains only partially realised in practice.

Network analysis reveals strong structural coupling between architectural adaptability and operational coordination. Indicators associated with modular layouts and integrated sensing consistently align with flow management systems. This alignment confirms that operational intelligence depends fundamentally on spatial permissiveness. Predictive algorithms may identify bottlenecks or demand surges with increasing accuracy. Yet rigid spatial layouts frequently prevent meaningful operational response. Architecture, therefore, is positioned within the reviewed literature as mediating the translation of digital insight into physical action. Smartness emerges only when this translation can occur dynamically and reliably.

A clear divergence appears between greenfield and brownfield airport development contexts. Digitally native greenfield airports embed adaptability into architectural systems from inception (Keskin *et al.*, 2020; Keskin, 2021). Features such as swing gates and reconfigurable partitions enable dynamic spatial reorganisation. In these environments,

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architecture functions as a cyber-physical actuator for operational intent. Brownfield airports present a contrasting condition shaped by legacy constraints (Keskin, 2021). Existing layouts often limit the use of advanced operational software despite comparable levels of technological investment.

This digital–physical mismatch represents a structural limitation rather than a transitional inefficiency. Retrofitted terminals often lack the spatial permissiveness required for adaptive operations. Operational intelligence is therefore throttled by architectural rigidity rather than technological capacity. These findings challenge assumptions that software optimisation can compensate for fixed infrastructure. Instead, adaptability must be co-designed across physical and digital layers. Smartness emerges through alignment rather than modular technological upgrades alone.

The interface also exposes a temporal tension within smart airport systems. Architectural decisions are, by necessity, long-term and capital-intensive. Operational systems evolve rapidly through software updates and data integration cycles. Misalignment between these temporal scales undermines system resilience over time. Systems become optimised for specific scenarios yet vulnerable to unexpected disruption. Adaptability must therefore be treated as a systemic condition rather than a discrete technological feature.

3.3 Operational efficiency: network structure and adaptive coordination

Operations as the Adaptive Engine: Operational Efficiency emerges as the most structurally dominant domain within the smart airport network (Moghadasnian, 2024; Zhang *et al.*, 2023). Unlike architecture, which supports coordination between systems, operations regulate flow, resource coordination, and performance across airport environments (Semykina and Litoshenko, 2024; Benini and Borille, 2023). The network analysis indicates that operational performance depends on the coordination of interconnected subsystems, including passenger processing, resource allocation, airside coordination, and performance monitoring (Ma *et al.*, 2023; Zhong and Liu, 2020). This aligns with research that treats airports as closely connected service systems (Svitek *et al.*, 2021; Wattanacharoensil *et al.*, 2021).

Dictionary-based theme frequencies across the SLR period show consistent attention to operational control constructs. Queue management, capacity coordination, and monitoring indicators recur across diverse study designs. This consistency suggests operations evolve through incremental capability building, not isolated interventions (Nikolić *et al.*, 2024; Moghadasnian, 2024). It also supports reproducibility, because the narrative is anchored to recurring constructs in the bounded corpus. Document-level co-occurrence patterns further show operational indicators intersect with technology and experience themes (Moghadasnian, 2024; Miskolczi *et al.*, 2021).

The network analysis of the top ten operational sub-indicators, visualised in Figure 5, shows a coherent coordination structure. Rather than linear process chains, the network indicates feedback loops between monitoring, control, and resource decisions. These loops help the system adjust to demand variability in real time (Ma *et al.*, 2024a; Tang *et al.*, 2023a, b). The network metrics identify ten sub-indicators with disproportionate influence in the operational domain. Their influence reflects their role in linking operational processes across the network rather than simple frequency alone.

Figure 5 illustrates that operational efficiency relies on coordination, with dense connections clustering around control and flow-regulation nodes. Cross-cluster links indicate strong bridging behaviour (Wang *et al.*, 2021; Zhang *et al.*, 2023), suggesting the system functions as a continuously recalibrated control structure rather than a linear chain (Ma *et al.*, 2024a). Table 9 ranks the sub-indicators holding this structure together, distinguishing between nodes that stabilise the network and bridging concepts that integrate airside, landside, and passenger domains. Applying the same cumulative network-ranking procedure described above, Table 9 presents the ten highest-ranked Operational Efficiency sub-indicators.

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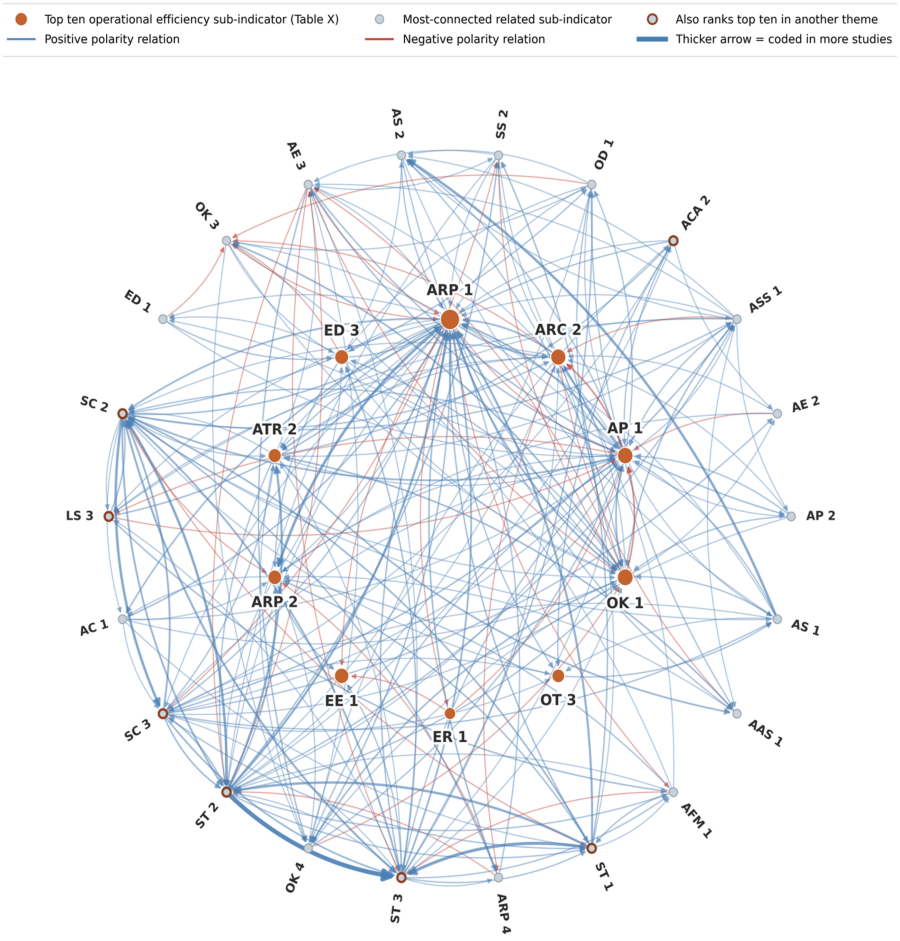


Figure 5. Network analysis of top 10 sub-indicators: operational efficiency. The network illustrates a coherent coordination structure defined by feedback loops rather than linear process chains. The high density of connections around control and monitoring nodes indicates that operational smartness relies on the continuous synchronisation of interdependent processes rather than isolated task optimisation. Sub-indicator codes are defined in Table 9

3.3.1 Interpretation of key operational efficiency sub-indicators. ARP 1: Operational Efficiency occupies a central coordinating position within the operational network. High betweenness indicates that it bridges otherwise separate clusters, aligning automation, service routines and performance evaluation into a single control narrative (Moghadasnian, 2024; Ma *et al.*, 2023). In the SLR, "efficiency" is viewed as an ongoing synchronisation of interdependent processes amid variability (Benini and Borille, 2023). This positions operational efficiency as a central coordinating function within the network.

ARC 2: Customer Experience Enhancement sits near the centre because it links interventions to outcomes within the same decision cycle. Its bridging behaviour suggests that experience functions as both a constraint and an evaluative target for operational tuning,

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not a post-optimisation scorecard (Zhang *et al.*, 2022; Ma and Ma, 2022). Studies have highlighted the connection between service quality, brand experience, and perceived value. These elements rely on consistent processes and well-maintained facilities (Ma and Ma, 2022; Hong *et al.*, 2020). Additionally, the passenger experience provides an important evaluative perspective on whether operational efficiency is reflected in the quality of services delivered to customers.

AP 1: Queue Management Services forms the flow-control spine that connects sensing, allocation, and sequencing. Its connectivity reflects how queue states are associated with operational responses to demand uncertainty, treated in the literature as an intelligence function rather than a passive throughput outcome (Ma *et al.*, 2024b; Zhong and Liu, 2020). Decision support work shows that queue conditions are used to inform reconfiguration of lanes, staffing and service rules, linking physical constraints to analytics-driven control loops (Grahn and Jacquillat, 2020; Ma *et al.*, 2024b).

OK 1: Passenger Wait Times acts as a prominent feedback-related indicator within this operational structure. The network's role involves more than just reporting; it requires continuous monitoring paired with real-time adjustments (Grahn and Jacquillat, 2020; Yuan and Jiang, 2023). In this context, timestamps and wait times are commonly used as operational signals that inform recalibration, particularly in turnaround efficiency and process-control research (Zoutendijk and Mitici, 2024; Yuan and Jiang, 2023). Co-occurrence with service quality and satisfaction constructs in the corpus further indicates that performance is interpreted in terms of passenger-visible time costs.

ED 3: Resource Allocation functions as the tactical coordination node across people, space and time. Its connectivity reflects the idea that smartness depends on feasible reallocations under demand variability, consistent with robust planning and scheduling research that emphasises constraints, contingencies, and resource coupling (Suriyanarayanan *et al.*, 2022; Wang *et al.*, 2021). Utilisation and IoT-based frameworks similarly treat allocation as a measurable optimisation problem, explaining its links to queue control, monitoring and cost narratives (Mrňa *et al.*, 2021; Zhou, 2023).

OT 3: Satisfaction with Newly Adopted Technologies bridges deployment success to user acceptance. Its weaker embedding is analytically coherent because adoption spans loosely coupled services (Rubio-Andrada *et al.*, 2023; Pant, 2022). Studies on technology readiness and adoption shows that perceived usefulness is essential for sustained use. Therefore, this node emphasises the link between innovation rollouts and experiential evaluation, rather than core control logic (Min and Jo, 2022; Mwesiumo *et al.*, 2023). Prioritising user experience helps ensure new technologies are effectively embraced.

ER 1: Runway Capacity appears as a boundary condition that couples landside operations to airside constraints. The bridging pattern reflects coordination effects rather than dense internal integration (Ma *et al.*, 2022b, 2023). Slot allocation and airside uncertainty influence terminal scheduling and staffing. The modelling approach considers runway limits as important factors that shape feasible operational scenarios (Ma *et al.*, 2023; Tang *et al.*, 2023a, b). Operational efficiency is therefore conditioned by an airside–landside performance system.

EE 1: Energy Consumption operates as a cross-domain monitoring node. Its position suggests energy is captured through operational routines and then managed through efficiency narratives (Xianliang *et al.*, 2021; Yildiz *et al.*, 2022). Empirical work links airport energy demand to activity patterns, climate exposure and scheduling. Predictive and spatiotemporal studies establish a connection between passenger dynamics and resource loads (Xianliang *et al.*, 2021; Ma *et al.*, 2024a). This relationship helps to explain the role of energy in operational processes, sustainability efforts, and performance management discussions.

ARP 2: Cost Savings links operational change to investment justification and governance. The network role implies that finance legitimises programmes more than it drives day-to-day control logic (Pagliara and Zingone, 2023; Remencová and Sedláčková, 2021). Efforts to develop BIM-centred ecosystems and lifecycle value frameworks integrate digital technologies to achieve efficiency gains and long-term value (Xiao, 2021; Xiong and

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Wang, 2022). This approach is bolstered by sustainable performance studies that emphasise cost reduction through structured evaluation and disclosure.

ATR 2: Baggage Tracking Systems enhance logistical visibility, fostering passenger reassurance and trust. This connection illustrates how operational transparency is evident at the service interface (Valarmathy *et al.*, 2023; Si *et al.*, 2021). Studies on IoT and tracking indicate that enhanced visibility supports effective exception handling and reduces uncertainty during disruptions (Noel *et al.*, 2021; Valarmathy *et al.*, 2023). This positions baggage tracking as both an operational control mechanism and a contributor to passenger reassurance.

Overall, the operational network functions as a coordinated system in which efficiency provides the organising structure. Within this structure, experience supplies legitimacy and constraints, queues and wait times form the observable control loop, and allocation enables implementable action. Crucially, the boundary, adoption, sustainability, and governance nodes then condition whether the resulting gains are deliverable and durable.

3.3.2 Synthesis of operational efficiency network insights. The operational network indicates that operational performance depends on coordinated feedback rather than isolated optimisation processes. Highly connected nodes stabilise core routines, while bridging nodes integrate decisions across subsystems (Nikolić *et al.*, 2024; Yuan and Jiang, 2023). Flow-control and monitoring nodes translate demand variability into timely operational interventions (Suriyanarayanan *et al.*, 2022; Ma *et al.*, 2024a). Experience and adoption nodes ensure that changes remain legible and acceptable to passengers. Meanwhile, energy and cost nodes connect operational control to accountability and provide justification for the program (Rubio-Andrada *et al.*, 2023; Soares and Wang, 2021). Overall, operational efficiency operates as the adaptive engine that converts data into coordinated action.

The operations–experience interface represents one of the most delicate balances in smart airport transformation. Operational systems prioritise throughput, predictability, and security across increasingly complex environments. Passenger experience, by contrast, is shaped by comfort, clarity, and perceived control. These objectives have historically been treated as competing priorities. The results demonstrate that digital integration is reshaping this relationship. Efficiency and comfort can be partially reconciled through coordinated system design. Experience increasingly emerges from operational configuration rather than supplementary service provision.

Network analysis reveals dense structural connections between operational flow management and experiential touchpoints. Indicators associated with biometric processing and real-time information frequently bridge both domains. Passenger experience is therefore increasingly embedded within operational logic. Amenities alone no longer define experiential quality. Instead, experience depends on how effectively operational processes are rendered invisible and intelligible. When systems operate effectively, passenger attention shifts away from operational processes and towards the continuity of the journey.

Biometric identification represented by node SBA 1 in Table 10 plays a central role in resolving the efficiency–comfort paradox (Jain *et al.*, 2011). Continuous identity verification reduces reliance on discrete security checkpoints. Border and security processes are becoming more integrated into the passenger journey. This dematerialisation lowers perceived waiting and enhances flow continuity. Operational control is maintained without visible interruption. Experience improves through reduced friction rather than increased interaction.

However, this integration introduces new forms of tension. Extensive data capture raises concerns related to privacy, consent, and trust. As noted in the literature, the deployment of new security technologies often generates public apprehension regarding ethical boundaries and privacy preservation (Malik *et al.*, 2023; Zhang, 2019). While passengers may be willing to provide personal data, this is strictly conditional on perceived benefits and trust (Mwesiumo *et al.*, 2023). Furthermore, the structural linkage between surveillance systems and governance frameworks remains limited (Santamaria *et al.*, 2019; Lykou *et al.*, 2019). Although operational efficiency benefits from comprehensive data use—such as passenger profiling to reduce wait times (Satish *et al.*, 2023)—passenger trust depends on transparency,

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proportionality, and accountability. Without explicit governance, experiential gains may be undermined over time.

The results also highlight the declining visibility of human assistance within passenger processing systems. Automation increasingly dominates routine interactions across the journey. Automated systems perform efficiently under stable conditions. They struggle, however, during disruption or emotional distress. Passenger experience, therefore, remains dependent on hybrid operational models. The findings therefore suggest that technology functions most effectively when combined with accessible forms of human support.

3.4 Passenger experience: a network-based analysis

Passenger Experience as a System Interface: Within smart airport environments, passenger experience operates as the point at which architectural systems and operational processes become visible to users (Miskolczi *et al.*, 2021; Monge-Zamorano, 2023). Unlike architecture, which supports long-term spatial organisation, and operations, which manage flow and performance, passenger experience is shaped by immediacy, perception, and ease of interaction (Hong *et al.*, 2020). The literature increasingly suggests that passenger experience depends on coordinated information access, environmental reassurance, and smooth interaction with airport systems rather than on isolated amenities or hospitality features alone (Pipatpong, 2022; Zhang, 2019).

Dictionary-based theme frequencies indicate that passenger experience indicators expanded rapidly after 2020, reflecting heightened concern with health assurance, contactless interaction, and confidence restoration following the COVID-19 disruption. However, unlike operational efficiency, which demonstrates metric convergence around control and throughput, experiential indicators display functional dispersion (Pipatpong, 2022; Hong *et al.*, 2020). This pattern suggests that passenger experience is shaped by interactions among health, information, security, and comfort systems rather than by a single dominant factor (Macnaughton, 2022; Pipatpong, 2022).

Network analysis reinforces this interpretation by revealing a passenger experience network that is less densely clustered than the architectural or operational domains, yet characterised by pronounced betweenness across domains. As visualised in Figure 6, passenger experience is shaped through coordination between operational systems, architectural environments, and user perception, with experience-related sub-indicators frequently acting as bridges between operational systems, architectural environments, and human perception (Ma and Ma, 2022; Wattanacharoensil *et al.*, 2021). Highly connected nodes stabilise perceptions of safety, comfort, and reassurance, while bridging nodes translate operational states and environmental conditions into signals understandable to passengers (Ma *et al.*, 2022a; Mrňa *et al.*, 2021). Unlike operational networks, which regulate performance through closed feedback loops, the experiential network shapes trust and confidence through continuity of information and perceived control across the journey.

Table 10 identifies the ten passenger experience sub-indicators with the greatest structural influence within this mediating configuration, ranked using the same cumulative network score. Rather than constituting a ranked service hierarchy, these indicators function as perceptual leverage points through which system intelligence becomes experientially legible. Some nodes anchor experiential stability, while others integrate otherwise separate health, security, informational, and comfort subsystems into a coherent passenger-facing environment (Pipatpong, 2022; Monge-Zamorano, 2023). Their influence lies less in operational throughput and more in shaping reassurance, confidence, and passenger understanding of the airport environment.

3.4.1 Interpretation of key passenger experience sub-indicators. HC 4 Air Filtration Systems emerges as the most structurally influential experiential indicator, functioning as the primary health-assurance anchor. Its high degree and bridging capacity reflect the literature's emphasis on invisible environmental control as a as an influence on perceived safety (Ma *et al.*,

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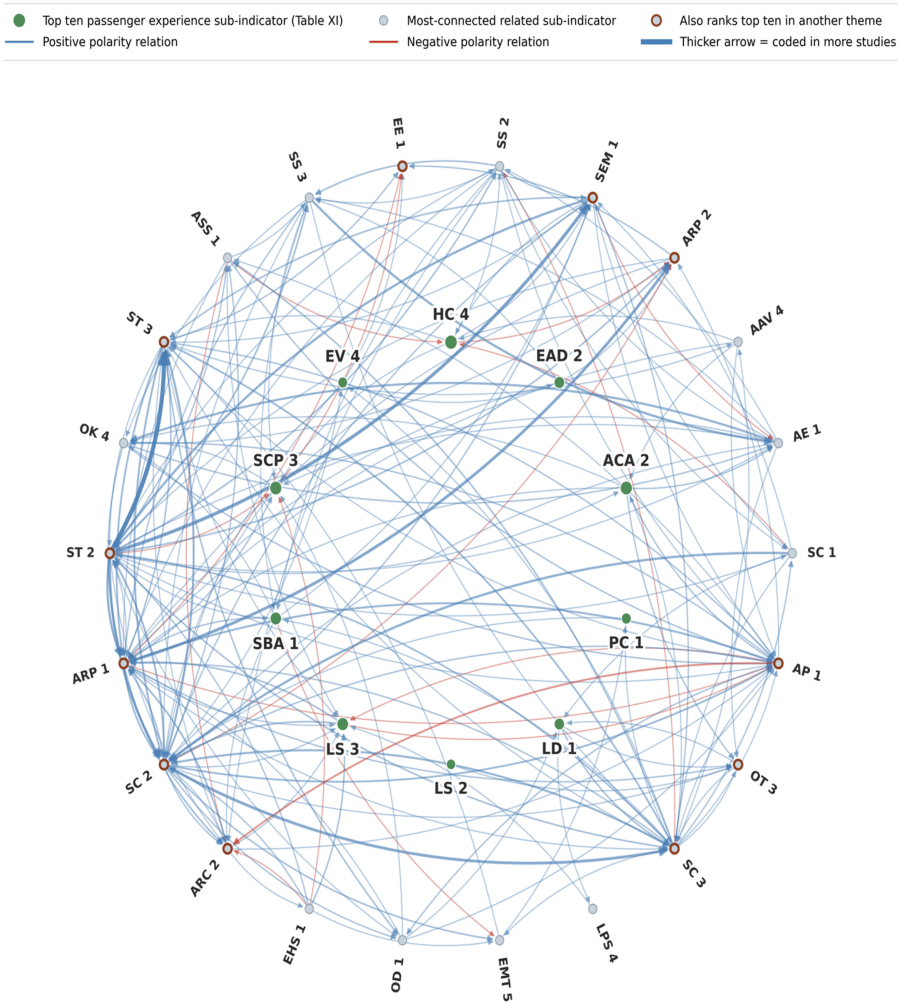


Figure 6. Network analysis of top 10 sub-indicators: passenger experience. The dispersed network structure indicates that experience is not associated with a single dominant node, but is shaped by the selective integration of health, information, and security subsystems. Sub-indicator codes are defined in Table 10

2024a; Macnaughton, 2022). Air quality management contributes to passenger reassurance even when these systems are not directly visible to users. They link building systems, hygiene protocols, and passenger wellbeing into a single perceptual construct (Ma *et al.*, 2022a; Macnaughton, 2022).

EAD 2 Mobile App Integration functions as a translational interface between passengers and the wider airport system. Its network role is primarily mediatory, enabling access to real-time information, navigation support, and service personalisation (Mrňa *et al.*, 2021; Samha *et al.*, 2020). The literature positions mobile platforms as mechanisms for restoring passenger

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agency in complex, uncertain terminal environments, particularly during disruptions or dynamic reconfiguration (Stojić *et al.*, 2023; Ma *et al.*, 2024b).

ACA 2 Baggage Handling Automation occupies a structurally influential position by linking back-of-house reliability to passenger trust. Automated tracking and handling systems are associated with reduced uncertainty around asset location, so that logistical transparency is discussed as an experiential attribute (Valarmathy *et al.*, 2023; Si *et al.*, 2021). This positioning reflects a shift in the literature, where operational reliability increasingly contributes to experiential reassurance rather than remaining operationally invisible (Halpern and Mwesiumo, 2021; Ma and Ma, 2022).

PC 1 Real-Time Flight Updates operates as a coordination node connecting operational status with passenger decision-making. Its influence derives from integration rather than visibility, as flight information gains experiential value (Yuan and Jiang, 2023; Zhong and Liu, 2020). Its value depends on consistent coordination across displays, mobile platforms, and public address systems. The network position indicates that situational awareness is associated with continuity and consistency, not information abundance (Narongou and Sun, 2022; Alansari *et al.*, 2019).

LD 1 Online Catalogue bridges digital commerce and physical dwell environments, reflecting the growing role of pre-engagement and personalised retail in shaping perceived value during waiting periods (Wu and Tsui, 2020; Miskolczi *et al.*, 2021). Its presence within the top-tier network highlights how experiential quality increasingly extends beyond movement efficiency into the management of dwell time and discretionary engagement (Monge-Zamorano, 2023; Pipatpong, 2022).

LS2 Comfortable Seating and *LS3 Amenities* together anchor the physical comfort layer of the experiential system (Pipatpong, 2022; Ma *et al.*, 2022b). Amenities exhibit higher connectivity because they consolidate multiple supporting services into a single node. Seating, by contrast, performs a more focused function, associated with passenger wellbeing during periods of enforced waiting (Ma and Ma, 2022; Pivac *et al.*, 2022). Taken together, these elements underline the continued importance of tangible spatial conditions, even as airport environments become increasingly digitally mediated.

SBA 1 Types of Biometrics Used and *SCP 3 Security Measures Implemented* function as critical bridges between security operations and experiential flow. The current network position illustrates a shift towards seamless security models (Khan and Efthymiou, 2021; Zhang, 2019). In these models, identity verification is spread across the entire journey rather than confined to specific checkpoints. This approach is described in the literature as integrating verification more fluidly throughout the user experience (Pik, 2024; Zhang, 2019). This integration reduces visible interruption while maintaining operational control, aligning with literature on "walk-through" security paradigms.

EV 4 Integration with Real-Time Flight Information links immersive and entertainment systems with operational data streams. The primary role is to foster experiential engagement while ensuring that passengers remain informed about system status (Tran *et al.*, 2022; Mäkelä, 2024). This approach highlights the integration of information, entertainment, and reassurance in modern terminal environments (Pipatpong, 2022; Zhuo, 2023).

3.4.2 Synthesis of passenger experience network insights. The passenger experience network demonstrates that passenger experience is shaped through the coordination of health assurance, information access, security integration, and comfort-related systems rather than through individual technologies or amenities alone. Highly connected indicators stabilise the experience environment, while bridging indicators link passengers to operational and architectural systems.

Unlike Operational Efficiency, where metric convergence signals dominance, the passenger experience domain relies on selective integration. Its sub-indicators shape perception, trust, and agency rather than throughput or performance (Moghadasnian, 2024; Wattanacharoensil *et al.*, 2021). This positions passenger experience as a connecting layer between airport systems and passenger response.

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The architecture–experience interface foregrounds the embodied and cognitive dimensions of smart airport environments. Digital systems mediate information delivery and passenger movement. Physical space shapes perception, stress, and emotional response throughout the journey. The results demonstrate that passenger experience is co-produced by spatial conditions and digital augmentation. Technology alone does not determine experiential quality. Architecture remains central to how passengers feel, orient themselves, and behave. Passenger experience is therefore shaped through both physical space and digital interaction.

Network patterns (Figure 6) reveal strong alignment between architectural features and experiential indicators, such as "comfortable seating" (LS 2). Biophilic design, spatial legibility, and environmental control correlate with well-being outcomes. Lighting and acoustics play significant roles in regulating stress and attention. These features influence movement patterns and cognitive load. Architecture actively shapes passenger behaviour under varying conditions. Experiential intelligence, therefore, depends on spatial coherence and environmental stability.

Digital systems amplify architectural effects rather than replacing them. Sensors and analytics enable environments to respond dynamically to contextual change. Lighting, temperature, and soundscapes adjust according to density and time. Such responsiveness supports comfort and reduces cognitive overload. Architecture, therefore, operates as a responsive environment rather than a fixed physical backdrop. Digital augmentation strengthens, rather than substitutes for, spatial intelligence.

A tension emerges between experiential well-being and commercial imperatives in terminal environments. Advertising displays and immersive retail compete for passenger attention, often taxing cognitive bandwidth. While commercial systems enhance revenue by driving discretionary passenger activity (Mekic *et al.*, 2021), they may disrupt clarity in wayfinding and the overall "airportscape" (Wattanacharoensil *et al.*, 2021). As noted in the literature, the airport environment fundamentally shapes destination image and passenger behaviour (Pipatpong, 2022); yet, network analysis reveals weak coordination (low edge weight) between wayfinding and commercial interfaces. Experiential priorities are therefore inconsistently managed at the architectural level, suggesting a need to balance purely commercial drivers with cultural or heritage experiences to maintain a coherent sense of place (Monge-Zamorano, 2023).

This attention conflict highlights the limits of digital mediation. Additional screens do not necessarily improve passenger experience. Excessive stimulation can increase stress and disorientation. These effects are particularly pronounced for unfamiliar or time-pressured travellers. Experiential intelligence requires restraint alongside technological sophistication. The findings, therefore, suggest that effective passenger experience depends more on clarity and coherence than on increasing levels of digital stimulation.

3.5 Transversal dynamics: technology, sustainability, and governance

Beyond domain-specific indicators, the network analysis reveals transversal patterns spanning architectural, operational, and experiential subsystems. Two such patterns emerge with particular clarity across the network structure. Technology functions as an enabling layer that connects otherwise discrete domains. Sustainability, by contrast, appears as an outcome that remains weakly embedded within passenger-facing and operational structures. Together, these transversal dynamics indicate that smart airport systems currently prioritise integration and operational efficiency more strongly than broader sustainability objectives.

Technology-related indicators demonstrate consistently high cross-domain connectivity across the network. They operate as integrative mechanisms rather than isolated technological solutions. Sustainability indicators, however, display uneven structural positioning. Efficiency-oriented constructs are embedded within specific subsystems. Broader sustainability objectives remain peripheral across operational and experiential networks. This asymmetry suggests that technological integration has matured into a system-level logic.

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Sustainability, therefore, appears more as a consequence of efficiency-driven optimisation than as a central organising principle within the network.

3.5.1 Technology as a transversal enabler. Technology functions within the network as a connecting layer across architectural, operational, and experiential systems. Digital technologies do not operate as a standalone layer. Instead, they function as connective infrastructure supporting real-time data exchange and adaptive control. High betweenness scores associated with digital platforms indicate their mediating role across subsystems. These platforms link physical environments, operational processes, and passenger interfaces.

Indicators associated with artificial intelligence, the Internet of Things, and digital twins occupy consistent bridging positions. Their influence does not derive from direct passenger visibility. It arises from their capacity to synchronise sensing, prediction, and decision-making processes. Digital twins exemplify this transversal role particularly clearly. They connect architectural configurations with operational scenarios and experiential outcomes through simulation and feedback.

The network structure, therefore, positions technology as a precondition for system-wide coordination. Technology is not presented as an end in itself. This finding aligns with broader shifts in smart infrastructure discourse. Current research increasingly views airport performance as dependent on the coordination of integrated systems rather than on isolated digital tools alone.

3.5.2 Sustainability as an emergent outcome. In contrast to technology, sustainability indicators exhibit a more fragmented structural presence. Efficiency-oriented constructs such as energy optimisation are embedded within architectural systems. Broader sustainability objectives remain structurally peripheral. These include net-zero operations and behavioural change mechanisms. This distribution suggests that sustainability is not yet consistently integrated across architectural, operational, and experiential systems (Ghaffarianhoseini *et al.*, 2017b). Instead, it occupies a marginal position within the smart airport system.

The network reveals two distinct gaps in sustainability operationalisation. One gap is that sustainability remains largely confined to infrastructural performance metrics. It rarely extends into operational decision-making or passenger engagement. A second gap appears in passenger-facing systems. Sustainability indicators show limited integration with experiential systems capable of shaping passenger awareness or action. These patterns reflect trends within the literature rather than direct performance assessments. They expose limitations in how sustainability is conceptualised and operationalised.

As a result, sustainability is primarily realised as an emergent outcome of efficiency-driven interventions. It is not integrated as a socio-technical objective shaping system design or governance. Passenger interaction remains weakly connected to sustainability logics (Bulkeley *et al.*, 2016). The structural asymmetry revealed in the network analysis—where technology acts as a central enabler while sustainability remains peripheral—points to a systemic limitation. This imbalance also points to broader governance limitations within smart airport systems. The preceding discussion demonstrates that smart airport transformation is constrained by integration capacity rather than technological availability. Systems increasingly exchange data across architectural, operational, and experiential domains. Governance structures have not evolved at a comparable pace. This imbalance foregrounds governance as a critical limitation. Technical interoperability frequently outpaces institutional coordination. As a result, system coherence remains fragile. The analysis reveals a clear asymmetry between technical and governance integration. Operational platforms link architecture and passenger experience in real time. Data ownership, accountability, and decision authority remain weakly articulated. This produces a governance lag within smart airport systems (Kitchin, 2014). Ethical risks intensify as autonomy and automation expand. Privacy and accountability, therefore, become structurally vulnerable.

This governance gap is particularly visible in the treatment of sustainability. Sustainability rarely functions as a primary organising logic within smart airport systems. Instead, it emerges indirectly through efficiency-driven interventions. Energy optimisation and automation

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deliver measurable environmental benefits. Broader sustainability objectives remain peripheral. Sustainability is therefore treated as an outcome rather than a guiding design principle. Efficiency-oriented sustainability introduces additional structural limitations. Short-term optimisation dominates over regenerative or adaptive strategies. Passenger-facing systems remain weakly connected to sustainability goals. Digital interfaces influence behaviour but are rarely leveraged for environmental engagement. This represents a missed opportunity within system design. Sustainability remains technically achieved but socially under-integrated. Governance also mediates the ethical and social consequences of smart airport systems. Surveillance technologies and predictive analytics intensify data-driven control. Concerns related to consent, proportionality, and fairness increase accordingly. Ethical oversight frameworks lag behind technical deployment. In some cases, efficiency priorities may outweigh broader equity considerations. Public trust, therefore, becomes increasingly fragile.

Collectively, the findings indicate a need for governance-led integration. Integration must extend beyond technical interoperability alone. Institutional alignment and accountability are equally critical. Governance should enable rather than constrain smart transformation. Long-term value depends on coordinated priorities across domains. Long-term smart airport development, therefore, depends on governance, technology, and design evolving in a coordinated manner.

4. Conclusion and future research directions

4.1 RQ closure and evidence-based synthesis

This study set out to address two research questions concerning the nature of smart airport transformation and the interrelationships shaping it across architectural, operational, and passenger-experience domains. Through a PRISMA-guided systematic literature review and network analysis of 511 peer-reviewed studies, the research provides a structured, evidence-based synthesis of how smart airports are conceptualised and operationalised in contemporary scholarship.

In response to *Research Question 1—What are the key factors influencing smart airport transformation within the domains of architecture, operational efficiency, and passenger experience?*—this study identifies a comprehensive set of 433 validated sub-indicators derived from the reviewed corpus. These factors are systematically documented and analysed across the three domains of architecture, operational efficiency, and passenger experience. The results demonstrate that operational efficiency dominates the literature as the primary organising domain, structuring most smart-airport interventions around flow control, monitoring, and resource allocation. Architecture functions as a mediating system associated with the translation of digital intelligence into physical action, particularly where spatial rigidity limits adaptive operational responses. Passenger experience functions as a connecting layer shaped less by discrete amenities and more by information continuity, health assurance, and perceived control. Together, these findings indicate that smart airport transformation depends less on isolated technologies and more on coordination across interconnected systems.

Addressing *Research Question 2—How do factors across architecture, operational efficiency, and passenger experience interrelate to shape the transformation of new and transitioning airport environments?*—the cross-domain network results shows that the strongest relationships occur at the interfaces between domains rather than within individual subsystems. The architecture–operations relationship indicates that architectural adaptability and operational coordination are structurally coupled, particularly in brownfield contexts where legacy spatial constraints limit the realisation of advanced operational intelligence. The operations–experience interface further demonstrates that passenger experience is increasingly embedded within operational control logic, with flow management, biometric processing, and real-time information acting as bridging mechanisms. Comparative patterns

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between greenfield and brownfield environments suggest that digitally native contexts tend to exhibit tighter cyber-physical alignment than retrofitted terminals, where integration is more strongly shaped by spatial and organisational constraints.

Across both research questions, the findings show that effective smart airport development depends on alignment between physical infrastructure, digital systems, and passenger experience. Technology operates as a transversal enabler across domains, while sustainability appears primarily as a secondary outcome of efficiency-driven interventions rather than as a central organising principle. Governance is identified as a critical limiting condition, with institutional coordination often lagging behind technical integration. These findings collectively reinforce the central conclusion of the study: smart airport transformation is constrained less by technological availability than by the capacity to integrate architecture, operations, experience, and governance into a coherent system.

Consistent with this evidence, the study aligns with the following definition previously established in related work: A smart airport is a digitally enabled system that integrates architecture, operational efficiency, and passenger experience, with sustainability as the emergent outcome across both new and retrofit contexts.

Knowledge contribution. This paper contributes to the smart airport body of knowledge by consolidating a fragmented literature into a validated, cross-domain set of 433 sub-indicators and by showing, through network analysis, that transformation is driven primarily by cross-domain dependencies rather than discrete technologies. The resulting evidence-based map provides both a structured conceptual basis for future research and a practical tool for understanding where integration effort is most likely to influence system-wide outcomes.

4.2 Theoretical implications

This review contributes to the smart airport literature by reframing smart airport transformation as a structurally contingent process rather than a purely technology-driven progression. By synthesising evidence across architectural, operational, and passenger-experience domains, the findings show that digital technologies derive their transformative capacity from alignment with spatial configurations and organisational arrangements. This challenges linear or maturity-model interpretations of smart airport development and instead supports a systems-oriented view in which physical infrastructure, digital systems, and governance structures evolve together. Consistent with this synthesis, smart airports are best understood as digitally enabled systems that integrate architecture, operational efficiency, and passenger experience, with sustainability as the emergent outcome across both new and retrofit contexts.

Although sustainability emerges in this synthesis as an outcome of smart airport transformation rather than an already integrated design logic, its positioning can be interpreted through the lens of the United Nations Sustainable Development Goals (SDGs). In particular, the system-level emphasis on digitally enabled infrastructure integration aligns most directly with SDG 9 (Industry, Innovation and Infrastructure), while the climate-oriented sustainability constructs captured in the literature connect to SDG 13 (Climate Action) (United Nations, 2025a, d). Where energy optimisation and efficiency appear as enabling mechanisms, these also relate to SDG 7 (Affordable and Clean Energy) (United Nations, 2025c). Framed in SDG terms, the review highlights that smartness currently supports sustainability largely indirectly—through efficiency-led coordination and optimisation—indicating a need for stronger governance and accountability mechanisms to embed sustainability objectives across design, operations, and performance monitoring, consistent with SDG 17 (Partnerships for the Goals) (United Nations, 2025b; International Civil Aviation Organization, 2025).

The identification of recurring cross-domain dependencies also points to the value of network-oriented approaches for studying complex airport systems. For the wider academic community, the review provides a consolidated conceptual basis for examining smart infrastructure transitions, particularly in brownfield contexts where legacy spatial and

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organisational constraints shape the effectiveness of digital innovation. In doing so, the study provides a platform for future empirical work that models smart airport transformation as an integrated socio-technical system, with the evidence-based dependency map offering a concrete way to represent and interrogate these interrelationships.

4.3 Practical implications

For airport management and policy-oriented audiences, the findings offer a practical way to move from broad "smart airport" ambitions to decisions about what to do first, what to fix, and what to govern more carefully. The evidence-based map helps in three main areas: sequencing investment, targeting retrofit effort, and tightening delivery governance.

First, the results support investment sequencing by showing that some components do not behave like optional add-ons; they function as the glue that allows improvements to travel across domains. A useful early focus is on the bridging layer that connects sensing, coordination, and passenger communication. ST2 (Integration of IoT Devices) is the most densely connected infrastructure layer, suggesting it as a practical priority for initiatives that depend on reliable data capture and system interoperability. Similarly, SC2 (Real-time Information Systems) acts as a communication spine, linking operational coordination with passenger information services. Treating these as enabling foundations reduces the risk of standalone deployments that appear technologically advanced on paper but struggle to scale or integrate across terminal systems and service channels.

Second, the map helps with retrofit prioritisation, particularly in brownfield terminals where space, phasing, and capital constraints shape what is realistic. The synthesis indicates that digital and analytical investments deliver more consistently when paired with adaptable architectural configurations and operational workflows that can respond to real-time conditions. In practical terms, the map can be used as a retrofit checklist to identify interventions that unlock multiple downstream benefits—especially those that improve flow management and operational responsiveness (for example, reconfigurable processing/queuing arrangements that can actually make use of real-time data rather than simply collecting it). This is useful for deciding where a targeted spatial adjustment will increase the return on digital capabilities already being introduced.

Third, the findings strengthen programme governance, because several high-impact components sit at the interfaces between functions rather than within a single team's remit. SC3 (Mobile and Web-Based Communication) is a good example of this interface role: it links system intelligence to passenger-facing interaction, which means its performance depends as much on data stewardship and service continuity as it does on the front-end channel itself. Using the map as a shared reference point can help clarify ownership for cross-cutting capabilities such as interoperability, privacy-by-design, and operational handover—areas that often determine whether passenger-facing improvements work reliably in practice.

These integration priorities also carry societal implications, since AI, sensing and passenger-facing digital systems concentrate privacy, biometric surveillance, cybersecurity and trust considerations at the same interfaces that carry the greatest structural load. The reviewed literature indicates that passenger willingness to provide personal data is conditional on perceived benefit and trust, and that transparency, proportionality and accountability shape whether efficiency gains are sustained (Mwesiumo *et al.*, 2023; Malik *et al.*, 2023). Questions of digital inclusion follow directly, as the corpus records provision for travellers with reduced mobility and reports variation in technology acceptance across passenger groups (Grahn and Jacquillat, 2020; Rubio-Andrada *et al.*, 2023; Pant, 2022). Where automated processing informs passenger-facing decisions, such as profiling used to manage waiting times, the reviewed evidence points to the need for explicit governance of algorithmic decision-making alongside the technical capabilities being introduced (Satish *et al.*, 2023; Kitchin, 2014).

Overall, the evidence-based map provides a structured way to assess readiness, prioritise integration work, and align design and operational choices with measurable smart-airport

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capabilities. It supports context-sensitive planning by making interdependencies visible, so airports can sequence initiatives more realistically and avoid treating "smartness" as a set of isolated technology purchases.

4.4 Limitations and future research

While these findings offer a robust framework for understanding integration challenges, they should be interpreted within specific boundaries. First, the restriction to English-language publications may exclude relevant studies and case evidence from non-English-speaking regions, potentially biasing the corpus towards Anglophone academic outputs. This is significant given that smart airport innovation is a global phenomenon, particularly in the Asia-Pacific region. Second, the 2019 to 2024 timeframe was intentionally narrow to capture Industry 4.0-driven transformation and post-pandemic resilience; however, this focus excludes earlier foundational theoretical contributions. Third, although the "human-in-the-loop" verification strategy mitigated algorithmic risk, no computational approach can entirely eliminate conceptual ambiguity (Miles *et al.*, 2014). Finally, although relationship polarity was coded and retained, the network analysis relies on recorded linkages as proxies for relationship strength, and the reported centrality measures do not weight relationships by valence or criticality.

Future research could extend this work by addressing these boundaries. Specifically, subsequent studies should incorporate sentiment classification to differentiate relationship valence and enhance interpretive precision regarding the quality of cross-domain interactions. Additionally, expanding the scope to include non-English literature and regional regulatory documents would provide a more granular view of how governance models differ across distinct geopolitical contexts.

Overall, the transition towards smart airports depends on effective integration across systems. Technology is necessary but insufficient on its own; sustainable progress requires aligned architecture, operations, experience, and governance. Long-term smart airport development depends on architecture, operations, passenger experience, and governance evolving in a coordinated manner.

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Supplementary material

The supplementary material for this article can be found online.

References

Alansari, Z., Soomro, S. and Belgaum, M.R. (2019), "Smart airports: review and open research issues", in *Lecture Notes of the Institute for Computer Sciences, Social Informatics and Telecommunications Engineering*, pp. 136-148, doi: 10.1007/978-3-030-23943-5_10.

Amiri, M.H. and Kuşakcı, A.O. (2024), "A scoping review of artificial intelligence applications in airports", *researchgate.net*, available at: https://www.researchgate.net/profile/Misagh-Haji-Amiri/publication/381853783_A_Scoping_Review_of_Artificial_Intelligence_Applications_in_Airports/links/668275ed2aa57f3b82643bca/A-Scoping-Review-of-Artificial-Intelligence-Applications-in-Airports.pdf

Batouei, A., Iranmanesh, M., Mustafa, H., Nikbin, D. and Ping, T.A. (2020), "Components of airport experience and their roles in eliciting passengers' satisfaction and behavioural intentions", *Research in Transportation Business and Management*, Vol. 37, 100585, doi: 10.1016/j.rtbm.2020.100585.

Downloaded from www.emerald.com/sasbe/article-pdf/doi/10.1108/SASBE-02-2026-0150/11898732/sasbe-02-2026-0150en.pdf by Auckland University of Technology user on 28 Octobe

Benini, E. and Borille, G.M.R. (2023), "Analysis of layout flexibility on the efficiency of airport passenger terminals", *TRANSPORTES*, Vol. 31 No. 2, e2716, doi: 10.58922/transportes.v31i2.2716.

Borgatti, S.P., Everett, M.G. and Johnson, J.C. (2018), *Analyzing Social Networks*, 2nd ed., Sage Publications, ISBN 9781526404107, available at: https://us.sagepub.com/en-us/nam/analyzing-social-networks/book262078 (accessed 20 June 2025).

Bulkeley, H., Broto, C., Vanesa and Edwards, G. (2016), "Governing sustainability transitions", *Environmental Policy and Governance*, Vol. 26 No. 2, pp. 87-102, doi: 10.1002/eet.1702.

Choorapulakkal, A. and Fadli, F. (2026), "Generative digital twinning for dynamic building codes in smart sustainable cities: a conceptual framework towards climate change adaptation", *Smart and Sustainable Built Environment*, pp. 1-17, doi: 10.1108/SASBE-02-2026-0094.

Di Vaio, A. and Varriale, L. (2020), "SDGs and airport sustainable performance: evidence from Italy on organisational, accounting and reporting practices through financial and non-financial disclosure", *Journal of Cleaner Production*, Vol. 249, 119431, doi: 10.1016/j.jclepro.2019.119431.

Freueman, L.C. (1977), "A set of measures of centrality based on betweenness", *Sociometry*, Vol. 40 No. 1, pp. 35-41, doi: 10.2307/3033543.

Geels, F.W. (2004), "From sectoral systems of innovation to socio-technical systems", *Research Policy*, Vol. 33 Nos 6-7, pp. 897-920, doi: 10.1016/j.respol.2004.01.015.

Gelhausen, M., Berster, P. and Wilken, D. (2021), "Post-COVID-19 scenarios of global airline traffic until 2040 that reflect airport capacity constraints and mitigation strategies". doi: 10.3390/aerospace8100300.

Ghaffarianhoseini, A., Tookey, J., Ghaffarianhoseini, A., Naismith, N., Azhar, S., Efimova, O. and Raahemifar, K. (2017a), "Building Information Modelling (BIM) uptake: clear benefits, understanding its implementation, risks and challenges", *Renewable and Sustainable Energy Reviews*, Vol. 75, pp. 1046-1053, doi: 10.1016/j.rser.2016.11.083.

Ghaffarianhoseini, A., Doan, D.T., Naismith, N., Ghaffarianhoseini, A. and Tookey, J. (2017b), "A critical comparison of green building rating systems", *Building and Environment*, Vol. 123, pp. 243-260, doi: 10.1016/j.buildenv.2017.06.039.

Gößling, S. (2020), "Risks, resilience, and pathways to sustainable aviation: a COVID-19 perspective", *Journal of Air Transport Management*, Vol. 89, 101933, doi: 10.1016/j.jairtraman.2020.101933.

Grahn, R. and Jacquillat, A. (2020), "Optimal escort dispatch for airport travelers with reduced mobility", *Transportation Research Part C: Emerging Technologies*, Vol. 111, pp. 421-438, doi: 10.1016/j.trc.2019.12.010.

Gürsel, S., Demir, R. and Rodoplu, H. (2023), "The effect of digitalisation on sustainability and smart airport", *International Journal of Sustainable Aviation*, Vol. 9 No. 1, pp. 26-40, ISSN 2050-0467, doi: 10.1504/IJSA.2022.10050096.

Halpern, N. and Mwesiumo, D. (2021), "Airport service quality and passenger satisfaction: the impact of service failure on the likelihood of promoting an airport online", *Research in Transportation Business and Management*, Vol. 41, 100667, doi: 10.1016/j.rtbm.2021.100667.

Hong, S.-J., Choi, D. and Chae, J. (2020), "Exploring different airport users' service quality satisfaction between service providers and air travelers", *Journal of Retailing and Consumer Services*, Vol. 52, 101917, doi: 10.1016/j.jretconser.2019.101917.

Hughes, T.P. (1987), "The evolution of large technological systems", in Bijker, W.E., Hughes, T.P. and Pinch, T. (Eds) *The Social Construction of Technological Systems: New Directions in the Sociology and History of Technology*, MIT Press, Cambridge, MA, pp. 51-82, available at: https://www.scirp.org/reference/referencespapers?referenceid=612715 (accessed 10 July 2024).

International Civil Aviation Organization (2025), "ICAO and the United Nations sustainable development goals (SDGs)", available at: https://www.icao.int/icao-and-united-nations-sustainable-development-goals (accessed 10 July 2025).

Jain, A.K., Ross, A. and Nandakumar, K. (2011), "Biometric recognition", *Proceedings of the IEEE*, Vol. 99 No. 8, pp. 1365-1388, doi: 10.1109/MPE.2011.940511.

Downloaded from www.emerald.com/sasbe/article-pdf/doi/10.1108/SASBE-02-2026-0150/11898732/sasbe-02-2026-0150en.pdf by Auckland University of Technology user on 28 Octobe

Jia, X., Macário, R. and Buyle, S. (2023), "Expanding horizons: a review of sustainability evaluation methodologies in the airport sector and beyond", Vol. 15 No. 15, 11584, doi: 10.3390/su151511584.

Keskin, B. (2021), "A building information modeling (BIM)-centric digital ecosystem for smart airport life cycle management", available at: https://search.proquest.com/openview/ef44c828daffaeb8721e64efa963774e/1?pq-origsite=gscholar&cbl=18750&diss=y

Keskin, B., Salman, B. and Ozorhon, B. (2020), "Airport project delivery within BIM-centric construction technology ecosystems", *Engineering Construction and Architectural Management*, Vol. 28 No. 2, pp. 530-548, doi: 10.1108/ecam-11-2019-0625.

Khan, N. and Efthymiou, M. (2021), "The use of biometric technology at airports: the case of customs and border protection (CBP)". doi: 10.1016/j.jjimei.2021.100049.

Kitchin, R. (2014), "The real-time city? Big data and smart urbanism", *GeoJournal*, Vol. 79 No. 1, pp. 1-14, doi: 10.1007/s10708-013-9516-8.

Kovynyov, I. and Mikut, R. (2019), "Digital technologies in airport ground operations", *Netnomics*, Vol. 20 No. 1, pp. 1-30, doi: 10.1007/s11066-019-09132-5.

Lunacek, M., Williams, L., Severino, J., Ficenec, K., Ugirumurera, J., Eash, M., Ge, Y. and Phillips, C. (2021), "A data-driven operational model for traffic at the Dallas fort worth international airport", *Journal of Air Transport Management*, Vol. 94, 102061, doi: 10.1016/j.jairtraman.2021.102061.

Lykou, G., Anagnostopoulou, A. and Gritzalis, D. (2019), "Smart airport cybersecurity: threat mitigation and cyber resilience controls", *Sensors*, Vol. 19 No. 1, p. 19, doi: 10.3390/s19010019.

Ma, G. and Ma, J. (2022), "The impact of airport facility service quality on brand experience and passenger satisfaction: considering the mediating role of brand engagement", *Future Transportation*, Vol. 2 No. 2, pp. 501-521, doi: 10.3390/futuretransp2020028.

Ma, G., Ding, Y. and Ma, J. (2022a), "The impact of airport physical environment on perceived safety and domestic travel intention of Chinese passengers during the COVID-19 pandemic: the mediating role of passenger satisfaction", *Sustainability*, Vol. 14 No. 9, p. 5628, doi: 10.3390/su14095628.

Ma, J., Zhou, J., Liang, M. and Delahaye, D. (2022b), "Data-driven trajectory-based analysis and optimization of airport surface movement", *Transportation Research Part C: Emerging Technologies*, Vol. 145, 103902, doi: 10.1016/j.trc.2022.103902.

Ma, W., Yuan, T. and Liu, N. (2023), "An application of operations research in airport ground path AI decision for apron operation control", *2023 IEEE 5th International Conference on Civil Aviation Safety and Information Technology (ICCASIT)*, IEEE, pp. 659-663, ISBN 979-8-3503-1060-3, doi: 10.1109/ICCASIT58768.2023.10351633.

Ma, K., Wang, D., Sun, Y., Wang, W. and Gu, X. (2024a), "Model predictive control for thermal comfort and energy optimization of an air handling unit system in airport terminals using occupant feedback", *Sustainable Energy Technologies and Assessments*, Vol. 65, 103790, doi: 10.1016/j.seta.2024.103790.

Ma, R., Huang, A., Jiang, Z., Wang, Z., Luo, Q. and Zhang, X. (2024b), "A data-driven optimal method for massive passenger flow evacuation at airports under large-scale flight delays", *Reliability Engineering and System Safety*, Vol. 245, 109988, doi: 10.1016/j.ress.2024.109988.

Macnaughton, P. (2022), "Building smart airports: technology solutions to improve health, enhance experience and increase revenue", *Henry Stewart Publications*, Vol. 16 No. 2, pp. 125-133, doi: 10.69554/jjds1391, available at: https://www.ingentaconnect.com/content/hsp;jsessionid=1glpr6k4h74n4.x-ic-live-02

Mäkelä, M. (2024), "Artificial intelligence to benefit the passenger experience at the airport", available at: https://www.theseus.fi/handle/10024/854179 (accessed 1 July 2024).

Malhotra, O., Dey, S., Foo, E. and Helbig, M. (2021), "Cyber security maturity model capability at the airports", *ACIS 2021 - Australasian Conference on Information Systems, Proceedings*, available at: https://aisel.aisnet.org/acis2021/55/

Downloaded from www.emerald.com/sasbe/article-pdf/doi/10.1108/SASBE-02-2026-0150/11898732/sasbe-02-2026-0150en.pdf by Auckland University of Technology user on 28 Octobe

Malik, H., Tahir, S., Tahir, H., Ihtasham, M. and Khan, F. (2023), "A homomorphic approach for security and privacy preservation of smart airports", *Future Generation Computer Systems*, Vol. 141, pp. 500-513, doi: 10.1016/j.future.2022.12.005.

Mekic, A., Mohammadi, Z., Sahand, S. and Sharpanskykh, A. (2021), "Systemic agent-based modeling and analysis of passenger discretionary activities in airport terminals", *Aerospace*, Vol. 8, doi: 10.3390/aerospace8060162.

Mijuskovic, A., Bemthuis, R., Aldea, A. and Havinga, P. (2020), "An enterprise architecture based on cloud, fog and edge computing for an airfield lighting management system", *Proceedings - IEEE International Enterprise Distributed Object Computing Workshop, EDOCW*, Vols 2020-Octob, pp. 63-73, ISBN 978-1-7281-6471-7, doi: 10.1109/EDOCW49879.2020.00021.

Miles, M.B., Huberman, M.A. and Saldaña, J. (2014), *Qualitative Data Analysis: A Methods Sourcebook*, 3rd ed., Sage Publications, ISBN 9781452257877, available at: https://us.sagepub.com/en-us/nam/qualitative-data-analysis/book234921 (accessed 10 July 2025).

Min, S.R. and Jo, D.H. (2022), "The effects of positive technology readiness in smart airports on integrated technology acceptance theories and information-sharing intentions", *Proceedings - 2022 IEEE/ACIS 7th International Conference on Big Data, Cloud Computing, and Data Science, BCD 2022*, pp. 306-310, ISBN 978-1-6654-6582-3, doi: 10.1109/BCD54882.2022.9900521.

Miskolczi, M., Jászberényi, M. and Tóth, D. (2021), "Technology-enhanced airport services–attractiveness from the travelers' perspective", *Sustainability*, Vol. 13 No. 2, p. 705, doi: 10.3390/su13020705.

Moghadasnian, S. (2024), "KPI-driven decision making in airport services: enhancing operational efficiency, customer satisfaction, and sustainability", available at: https://www.researchgate.net/publication/378142722

Mohammed, B.R., Jomaah, M.M. and Zehawi, R.N. (2021), "Emergence time phasing for the potential new airports in the middle district of Iraq", *International Journal of Design and Nature and Ecodynamics*, Vol. 16 No. 5, pp. 505-516, doi: 10.18280/ijdne.160504.

Molchanova, K. (2020), "A review of digital technologies in aviation industry", *Logistics and Transport*, available at: https://bibliotekanauki.pl/articles/1797206.pdf

Monge-Zamorano, M. (2023), "Cultural heritage experiences at the smart airport", *Journal of Tourism and Heritage Research*, Vol. 6 No. 1, pp. 281-299, ISSN 2659-3580, available at: https://www.jthr.es/index.php/journal/article/view/452

Mongeon, P. and Paul-Hus, A. (2016), "The journal coverage of Web of Science and Scopus: a comparative analysis", *Scientometrics*, Vol. 106 No. 1, pp. 213-228, doi: 10.1007/s11192-015-1765-5.

Mrňa, D., Badánik, B. and Novák, A. (2021), "Internet of Things as an optimization tool for smart airport concept", *European Transport - Trasporti Europei*, Vol. 82, doi: 10.48295/ET.2021.82.6.

Mwesiumo, D., Halpern, N., Bråthen, S., Budd, T. and Suau-Sanchez, P. (2023), "Perceived benefits as a driver and necessary condition for the willingness of air passengers to provide personal data for non-mandatory digital services at airports", *Transportation Research Part A: Policy and Practice*, Vol. 171, 103659, doi: 10.1016/j.tra.2023.103659.

Narongou, D. and Sun, Z. (2022), "Driving sustainable airport business with big data analytics services: a multichannel approach", *ACM International Conference Proceeding Series*, pp. 48-54, ISBN 978-1-4503-9677-6, doi: 10.1145/3564665.3564674.

Naung, Z.W., Purushothaman, M.B. and Ghaffarianhoseini, A. (2026), "LED airfield lighting: exploring the synergy of sustainable solutions, safety, and smart technology", *Smart and Sustainable Built Environment*, pp. 1-35, doi: 10.1108/SASBE-10-2025-0598.

Newman, M.E.J. (2010), *Networks: An Introduction*, Oxford University Press, doi: 10.1093/acprof:oso/9780199206650.001.0001.

Nikolić, M., Rakas, J. and Teodorović, D. (2024), "Formulation of the airport collaborative gate allocation problem and the bee colony optimization solution approach", *Engineering Applications of Artificial Intelligence*, Vol. 128, 107433, doi: 10.1016/j.engappai.2023.107433.

Downloaded from www.emerald.com/sasbe/article-pdf/doi/10.1108/SASBE-02-2026-0150/11898732/sasbe-02-2026-0150en.pdf by Auckland University of Technology user on 28 Octobe

Noel, S., Navya, M., Likitha, D., Manjula, K. and Keerthi Priya, S.V. (2021), "A smart IoT based real-time system to minimize mishandled luggage at airports", *Proceedings - 5th International Conference on Computing Methodologies and Communication, ICCMC 2021*, pp. 377-384, ISBN 978-1-6654-0360-3, doi: 10.1109/ICCMC51019.2021.9418041.

O'Connor, C. and Joffe, H. (2020), "Intercoder reliability in qualitative research: debates and practical guidelines", *International Journal of Qualitative Methods*, Vol. 19, pp. 1-13, doi: 10.1177/1609406919899220.

Page, M.J., McKenzie, J.E., Bossuyt, P.M., Boutron, I., Hoffmann, T.C., Mulrow, C.D., Shamseer, L., Tetzlaff, J.M., Akl, E.A., Brennan, S.E., Chou, R., Glanville, J., Grimshaw, J.M., Hróbjartsson, A., Lalu, M.M., Li, T., Loder, E.W., Mayo-Wilson, E., McDonald, S., McGuinness, L.A., Stewart, L.A., Thomas, J., Tricco, A.C., Welch, V.A., Whiting, P. and Moher, D. (2021), "The PRISMA 2020 statement: an updated guideline for reporting systematic reviews", *BMJ*, Vol. 372, p. n71, doi: 10.1136/bmj.n71.

Pagliara, F. and Zingone, M. (2023), "Providing resilience due to adverse weather events: a cost-benefit analysis for the case of the Milan Malpensa airport in Italy", *Journal of Air Transport Management*, Vol. 113, 102484, doi: 10.1016/j.jairtraman.2023.102484.

Pant, P. (2022), "Technology social practices by millennials and Gen Z at airport departure terminals", *Tourism Management Perspectives*, Vol. 43, 100978, doi: 10.1016/j.tmp.2022.100978.

Pik, E. (2024), "Airport security: the impact of AI on safety, efficiency, and the passenger experience", *Journal of Transportation Security*, Vol. 17 No. 1, 1938775X, doi: 10.1007/s12198-024-00276-6.

Pipatpong, F. (2022), "Examining the effect of airport environment on perceived image, memorable experiences and passenger relational behaviours", *Advances in Hospitality and Tourism Research (AHTR)*. doi: 10.30519/ahtr.1051578.

Pivac, J., Štimac, I., Vidović, A. and Boc, K. (2022), "Overview of the influence of level of service on the airport passenger terminal capacity", *Promet*, Vol. 34 No. 6, pp. 863-879, doi: 10.7307/ptt.v34i6.4203.

PRISMA Statement (2025), *Citing PRISMA 2020*, available at: https://www.prisma-statement.org/citing-prisma-2020 (accessed 12 May 2025).

Qian, C., Tang, W., Xiong, W., Chen, H. and Wang, Y. (2022), "Design and implementation of airport security system based on IoT data cloud platform", *2022 International Conference on Algorithms, Data Mining, and Information Technology (ADMIT)*, IEEE, Xi'an, pp. 62-67, ISBN 978-1-6654-5472-8, doi: 10.1109/ADMIT57209.2022.00019.

Ramakrishnan, J., Liu, T., Yu, R., Seshadri, K. and Gou, Z. (2022), "Towards greener airports: development of an assessment framework by leveraging sustainability reports and rating tools", *Environmental Impact Assessment Review*, Vol. 93, 106740, doi: 10.1016/j.eiar.2022.106740.

Ramakrishnan, J., Liu, T., Zhang, F., Seshadri, K., Yu, R. and Gou, Z. (2023), "A decision tree-based modeling approach for evaluating the green performance of airport buildings", *Environmental Impact Assessment Review*, Vol. 100, 107070, doi: 10.1016/j.eiar.2023.107070.

Reja, V.K., Fauth, J., MacAskill, K. and Brilakis, I. (2026), "Digital twins for smart cities: addressing shared influences in building permitting and road infrastructure planning", *Smart and Sustainable Built Environment*, pp. 1-29, doi: 10.1108/SASBE-09-2025-0558.

Remencová, T. and Sedláčková, A.N. (2021), "Modernization of digital technologies at regional airports and its potential impact on the cost reduction", *Transportation Research Procedia*, Vol. 55, pp. 18-25, doi: 10.1016/j.trpro.2021.06.003.

Rubio-Andrada, L., Celemín-Pedroche, M.S., Escat-Cortés, M.-D. and Jiménez-Crisóstomo, A. (2023), "Passengers satisfaction with the technologies used in smart airports: an empirical study from a gender perspective", *Journal of Air Transport Management*, Vol. 107, 102347, doi: 10.1016/j.jairtraman.2022.102347.

Safaeianpour, A. and Shamandi, N. (2022), "Smart airport: application of Internet of Things for confronting airport challenges", *publications.waset.org*, Vol. 16 No. 12, available at: https://publications.waset.org/10012847/smart-airport-application-of-internet-of-things-for-confronting-airport-challenges

Downloaded from www.emerald.com/sasbe/article-pdf/doi/10.1108/SASBE-02-2026-0150/11898732/sasbe-02-2026-0150en.pdf by Auckland University of Technology user on 28 Octobe

Şahin, İ.E. and Durmaz, V. (2023), "The road to smart airports: bibliometric analysis of digital transformation by using R language", *content.iospress.com*, pp. 1-28, doi: 10.3233/WOR-230737.

Samarasekara, H.M.S.N., Purushothaman, M.B. and Rotimi, F.E. (2024), "Interrelations of the factors influencing the whole-life cost estimation of buildings: a systematic literature review", *Buildings*, Vol. 14 No. 3, p. 740, doi: 10.3390/buildings14030740.

Samha, A.K., Alghamdi, N., Albader, H. and Alshammri, G.H. (2020), "Applied Internet of Things in Saudi Arabia airports", *16th International Computer Engineering Conference, ICENCO 2020*, pp. 103-111, ISBN 978-1-7281-6392-5, doi: 10.1109/ICENCO49778.2020.9357378.

Samuri, S., Fared, M., Khir, A., Amin, Z.M. and Mohammad, M.F. (2023), "Cybersecurity maturity framework for international airports in Malaysia: a systematic literature review (SLR)", *ir.uitm.edu.my*, Vol. 2, available at: https://ir.uitm.edu.my/id/eprint/87364/

Santamaria, A.F., Raimondo, P., Tropea, M., de Rango, F. and Aiello, C. (2019), "An IoT surveillance system based on a decentralised architecture", *Sensors*, Vol. 19 No. 6, p. 1469, ISSN 1424-8220, available at: https://doi.org/10.3390/s19061469 (accessed 19 July 2024).

Satish, A.S., Mangal, A. and Churi, P. (2023), "A systematic review of passenger profiling in airport security system: taking a potential case study of CAPPS II", *Journal of Transportation Security*, Vol. 16 No. 1, 8, doi: 10.1007/s12198-023-00260-6.

Schery, D., Alejandro, C., Caiado, R.G.G., Corseuil, E.T.L., Neves, H. and Weibull, J.K. (2025), "Multilevel analysis of the scientific trajectory of BIM: insights from SciVal and cumulative capability development perspective", *Engineering, Construction and Architectural Management*. doi: 10.1108/ECAM-05-2024-0688.

Semykina, O. and Litoshenko, H. (2024), "Functional and technological concepts of airports (past and present)", *Current Problems of Architecture and Urban Planning*, No. 68, pp. 62-71, doi: 10.32347/2077-3455.2024.68.62-71.

Si, P., Wang, F., Sun, E. and Su, Y. (2021), "BEI-TAB: enabling secure and distributed airport baggage tracking with hybrid blockchain-edge system", *Wireless Communications and Mobile Computing*, Vol. 2021 (Edited by Kadoch, M.), pp. 1-12, ISSN: 1530-8677, 1530-8669, available at: https://doi.org/10.1155/2021/2741435 (accessed 19 July 2024).

Siddiqui, F.M. (2019), "Digital transformation of modern airports by exploiting fog as a service model", Vol. 2019-April, 8735191, doi: 10.1109/ICNSURV.2019.8735191.

Siddiqui, F.M. and Mead, C.J. (2024), "Digital twin ConOps as a platform for airport master planning", *New Trends in Civil Aviation*, pp. 105-111, ISBN 978-80-01-07181-6, doi: 10.23919/NTCA60572.2024.10517818.

Soares, L. and Wang, H. (2021), "Economic feasibility analysis of charging infrastructure for electric ground fleet in airports", Vol. 2675 No. 12, pp. 1-12, doi: 10.1177/03611981211033859.

Sreenath, S., Sudhakar, K. and Yusop, A.F. (2021), "Energy-exergy-economic-environmental-energo-exergo-enviroecono (7E) analysis of solar photovoltaic power plant: a case study of 7 airport sites in India", *Sustainable Energy Technologies and Assessments*, Vol. 47, 101352, doi: 10.1016/j.seta.2021.101352.

Stojić, S., Dvořáková, T., Had, P. and Vittek, P. (2023), "Advanced airport virtual queueing utilizing smart city's infrastructure", *2023 Smart Cities Symposium Prague, SCSP 2023*, pp. 1-5, ISBN 979-8-3503-2162-3, doi: 10.1109/SCSP58044.2023.10146123.

Suriyanarayanan, R., Chati, Y.S. and Vasan, A. (2022), "Dynamic provisioning of airport resources for inbound passenger flow using reinforcement learning", Vol. 2022-October, pp. 619-626, doi: 10.1109/ITSC55140.2022.9922383.

Svitek, M., Rehor, V., Vittek, P. and Dvorakova, T. (2021), "Smart airports-developing demand side system services", *2021 Smart City Symposium Prague, SCSP 2021*, pp. 1-6, ISBN 978-0-7381-3158-0, doi: 10.1109/SCSP52043.2021.9447382.

Tan, J.H. and Masood, T. (2021), "Adoption of Industry 4.0 technologies in airports–a systematic literature review", arXiv: 2112.14333, available at: https://arxiv.org/abs/2112.14333

Downloaded from www.emerald.com/sasbe/article-pdf/doi/10.1108/SASBE-02-2026-0150/11898732/sasbe-02-2026-0150en.pdf by Auckland University of Technology user on 28 Octobe

Tang, H., Yu, J., Geng, Y., Wang, Z., Liu, X., Huang, Z. and Lin, B. (2023a), "Unlocking ventilation flexibility of large airport terminals through an optimal CO2-based demand-controlled ventilation strategy", *Building and Environment*, Vol. 244, 110808, doi: 10.1016/j.buildenv.2023.110808.

Tang, H., Yu, J., Lin, B., Geng, Y., Wang, Z., Chen, X., Yang, L., Lin, T. and Xiao, F. (2023b), "Airport terminal passenger forecast under the impact of COVID-19 outbreaks: a case study from China", *Journal of Building Engineering*, Vol. 65, 105740, doi: 10.1016/j.jobe.2022.105740.

Tran, T.H., Jiang, Y. and Williams, L. (2022), "Applications of mixed reality for smart aviation industry: opportunities and challenges", in *Modern Development and Challenges in Virtual Reality*, (Query date: 2024-07-10 12:21:21), available at: https://www.intechopen.com/chapters/84917

Ukwandu, E., Farah, M.A.B., Hindy, H., Bures, M., Atkinson, R., Tachtatzis, C., Andonovic, I. and Bellekens, X. (2022), "Cyber-security challenges in aviation industry: a review of current and future trends", Vol. 13 No. 3, p. 146, doi: 10.3390/info13030146.

United Nations (2025a), "Goal 13: climate action", available at: https://sdgs.un.org/goals/goal13 (accessed 10 July 2025).

United Nations (2025b), "Goal 17: partnerships for the goals", available at: https://sdgs.un.org/goals/goal17 (accessed 10 July 2025).

United Nations (2025c), "Goal 7: affordable and clean energy", available at: https://sdgs.un.org/goals/goal7 (accessed 10 July 2025).

United Nations (2025d), "Goal 9: industry, innovation and infrastructure", available at: https://sdgs.un.org/goals/goal9 (accessed 10 July 2025).

Valarmathy, S., Radhika, K., Bashkaran, K., Selvarasu, S. and Srinivasan, C. (2023), "Intelligent baggage management in airports: a cognitive IoT approach for real-time tracking, optimization, and passenger engagement", *7th International Conference on Electronics, Communication and Aerospace Technology, ICECA 2023 - Proceedings*, pp. 1876-1880, ISBN 979-8-3503-4060-0, doi: 10.1109/ICECA58529.2023.10395201.

Vonitsanos, G., Panagiotakopoulos, T., Kanavos, A. and Tsakalidis, A. (2021), "Forecasting air flight delays and enabling smart airport services in Apache Spark", Vol. 628, pp. 407-417, doi: 10.1007/978-3-030-79157-5_33.

Wang, S., Che, Y., Zhao, H. and Lim, A. (2021), "Accurate tracking, collision detection, and optimal scheduling of airport ground support equipment", *IEEE Internet of Things Journal*, Vol. 8 No. 1, pp. 572-584, doi: 10.1109/jiot.2020.3004874.

Wattanacharoensil, W., Graham, A., Fakfare, P. and Graham, A. (2021), "Airportscape and its effect on airport sense of place and destination image perception", *Tourism Review*, Vol. 77 No. 2, pp. 549-569, doi: 10.1108/tr-01-2021-0036.

Wennberg, L. (2019), "Our ambition is high: running the most climate-smart airport in the world", *Journal of Airport Management*, Vol. 13 No. 2, pp. 167-173, doi: 10.69554/JLDY6632.

Wongyai, P.H., Ngo, T., Wu, H. and Tsui, K. (2024), "Self-service technology in aviation: a systematic literature review", *Journal of Air Transportation*, (Query date: 2024-07-10 12:21:21), available at: https://www.sciencedirect.com/science/article/pii/S2941198X24000150

Wu, H. and Tsui, K.W.H. (2020), "Does a reward program affect customers' behavioural intention of visiting the airport? A case study of Singapore Changi airport", *Journal of Air Transport Management*, Vol. 82, 101742, ISSN 0969-6997, doi: 10.1016/j.jairtraman.2019.101742.

Xianliang, G., Jingchao, X., Zhiwen, L. and Jiaping, L. (2021), "Analysis to energy consumption characteristics and influencing factors of terminal building based on airport operating data", *Sustainable Energy Technologies and Assessments*, Vol. 44, 101034, doi: 10.1016/j.seta.2021.101034.

Xiao, L. (2021), "Application of smart site construction technology in civil airport airfield area", pp. 411-414, doi: 10.1109/ICHCESWIDR54323.2021.9656321.

Xiong, M. and Wang, H. (2022), "Digital twin applications in aviation industry: a review", *The International Journal of Advanced Manufacturing*, Vol. 121 Nos 9-10, pp. 5677-5692, doi: 10.1007/s00170-022-09717-9.

Downloaded from www.emerald.com/sasbe/article-pdf/doi/10.1108/SASBE-02-2026-0150/11898732/sasbe-02-2026-0150en.pdf by Auckland University of Technology user on 28 Octobe

Yildiz, O.F., Yilmaz, M. and Celik, A. (2022), "Reduction of energy consumption and CO2 emissions of HVAC system in airport terminal buildings", *Building and Environment*, Vol. 208, 108632, doi: 10.1016/j.buildenv.2021.108632.

Yuan, Y. and Jiang, X. (2023), "Wireless network-aided delay information system correlation with airport grid distribution based on multideterminants big data", *Mobile Information Systems*, Vol. 2023, pp. 1-11, doi: 10.1155/2023/1987326.

Zeng, C., Luo, J., Yuan, Y. and Haghighat, F. (2024), "Energy, economic, and environmental (3E) performance assessment, comparison, and analysis of airport cargo terminal microgrid system under the islanded and grid-connected modes", *Journal of Building Engineering*, Vol. 82, 108270, doi: 10.1016/j.jobe.2023.108270.

Zhang, Z. (2019), "Technologies raise the effectiveness of airport security control". doi: 10.1109/iccasit48058.2019.8973152.

Zhang, Y., He, L. and Liu, A. (2020), "AeroMACS application at HongQiao airport of China", *2020 IEEE 2nd International Conference on Civil Aviation Safety and Information Technology (ICCASIT)*, IEEE, pp. 1088-1093, ISBN 978-1-7281-9948-1, doi: 10.1109/ICCASIT50869.2020.9368627.

Zhang, Y., He, Q., Yang, L. and Liu, C. (2022), "An improved tunicate swarm algorithm for solving the multiobjective optimisation problem of airport gate assignments", *Applied Sciences*, Vol. 12 No. 16, p. 8203, doi: 10.3390/app12168203.

Zhang, R., He, D., Zhao, S., Qiao, Y. and Sui, Y. (2023), "Review of technologies of intelligent development of airport complex operation system", *Proceedings - 2023 Asia Symposium on Image Processing, ASIP 2023*, pp. 147-155, ISBN 979-8-3503-2342-9, doi: 10.1109/ASIP58895.2023.00032.

Zhong, M. and Liu, Y. (2020), "Research on the evaluation index system of the taxi operation and service in airport hubs", Vol. 325, 04005, doi: 10.1051/matecconf/202032504005.

Zhou, F. (2023), "Simulation-based optimization of bus departure scheme for large airport considering passenger evacuation", Vol. 5 No. 1, pp. 14-27, doi: 10.1108/srt-03-2023-0002.

Zhou, Y., Wen, M., Zhang, J. and Wang, D. (2023), "ViNavUT: vison based navigation system for unmanned tractor in airport", *Proceedings of the 2023 IEEE International Conference on Cybernetics and Intelligent Systems and IEEE Conference on Robotics, Automation and Mechatronics, CIS-RAM 2023*, pp. 158-163, ISBN 979-8-3503-0308-7, doi: 10.1109/CIS-RAM55796.2023.10370017.

Zhu, J., Zhao, X., Cao, Y. and Ma, M. (2023), "Design of a preliminary security check and smart access system at the entrance of airport terminal", *Proceedings of 2023 IEEE 5th International Conference on Civil Aviation Safety and Information Technology, ICCASIT 2023*, pp. 617-620, ISBN 979-8-3503-1060-3, doi: 10.1109/ICCASIT58768.2023.10351564.

Zhuo, P. (2023), "Application research of virtual reality technology in intelligent civil aviation airport visual management", Vol. 5 No. 2, pp. 109-112, doi: 10.54097/ajst.v5i2.6456.

Zoutendijk, M. and Mitici, M. (2024), "Fleet scheduling for electric towing of aircraft under limited airport energy capacity", *Energy*, Vol. 294, 130924, doi: 10.1016/j.energy.2024.130924.

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