

MAPPING AIRPORT COMPETITIVENESS RESEARCH: A COMBINED BIBLIOMETRIC AND STRUCTURAL TOPIC MODELING ANALYSIS

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Abstract

Background and Objective: Airport competitiveness has become an increasingly important issue in air transport economics, yet the literature remains fragmented across efficiency studies, market-access analyses, sustainability debates, and operational research. This study maps the contemporary knowledge base on airport competitiveness and clarifies how the field conceptualizes the phenomenon.

Study Design/Materials and Methods: The analysis is based on 303 publications indexed in the Web of Science Core Collection for 2015–2025, derived from an initial set of 433 records. The study combines descriptive bibliometrics, cited-reference co-citation analysis, document-level bibliographic coupling, and Structural Topic Modeling applied to titles, abstracts, and keywords.

Results: The results show a field that has moved from a relatively specialized niche toward a broader and more differentiated research domain. Co-citation mapping reveals an established intellectual core organized around performance measurement, efficiency, governance, and competition. Bibliographic coupling identifies active research fronts linked to benchmarking, connectivity and intermodality, sustainability transition, and digitally enabled airport operations. The STM results recover six topics and indicate a gradual shift from narrow benchmarking concerns toward wider agendas of regional development, resilience, sustainability, and operational intelligence.

Practical implications: For airport managers and public authorities, the findings suggest that competitiveness should be treated as a multidimensional capability shaped jointly by governance arrangements, infrastructure and investment decisions, network positioning, and transition readiness.

Conclusion and summary: The article shows that airport competitiveness is best understood not as a single performance indicator, but as the relative ability of airports to attract,

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coordinate, and sustain traffic and economic value under changing technological, environmental, and spatial conditions.

Keywords: airport competitiveness, bibliometrics, co-citation analysis, bibliographic coupling, structural topic modeling.

JEL classification: L93, R41, C38.

Paper type: research study.

1. Introduction

Airport competitiveness has become a central issue in contemporary air transport research because airports no longer function only as local infrastructure providers. In liberalized and increasingly commercialized aviation markets, they compete for airlines, routes, transfer flows, passengers, and strategic position within wider network systems. Competition therefore extends beyond neighboring airports that share a catchment area and increasingly reflects national and international network dynamics. Foundational studies showed that passenger airport choice is strongly shaped by access conditions in multi-airport regions, while later work demonstrated that competitiveness is also conditioned by airport investment, regional development, demand conditions, and institutional arrangements such as regulation and ownership (Pels et al., 2003; Cui et al., 2013).

At the same time, the literature relevant to airport competitiveness has expanded rapidly and diversified across several lines of inquiry. Scholars have examined efficiency and productivity, governance and privatization, financial performance, route development, accessibility, connectivity, and environmental sustainability. Yet this growth has not yielded a sufficiently clear account of how the field is organized intellectually or how its main lines of research relate to one another. Recent review evidence suggests that airport research remains strongly concentrated on efficiency and productivity, whereas other dimensions have developed unevenly and often in partial isolation. As a result, the literature offers many valuable empirical findings but still lacks a systematic synthesis of its canonical foundations, contemporary research fronts, and thematic evolution over time (Yu, 2023).

This gap matters because airport competitiveness is not a single performance outcome but a multidimensional and evolving construct. It encompasses operational capability, market attractiveness, spatial accessibility, network position, institutional flexibility, and the capacity to respond to external shocks. These pressures became especially visible during the last decade, when airports faced stronger inter-airport rivalry, rising sustainability expectations, and the disruption and recovery cycle associated with COVID-19. In this context, a conventional manual review can identify influential studies, but it is less effective in reconstructing the relational structure of a large corpus or in tracing latent thematic change across time.

Against this background, the present study adopts a combined bibliometric and text-analytic design to examine airport competitiveness research in publications indexed in the Web of Science Core Collection between 2015 and 2025. The analysis uses co-citation mapping to reconstruct the field's intellectual structure, bibliographic coupling to identify current research fronts, and Structural Topic Modeling to recover the latent thematic structure of the corpus and estimate how topic prevalence changes over time (Roberts et al., 2014). Rather than focusing on one airport, one region, or one performance metric, the article maps how the field is organized at three complementary levels: its canonical knowledge base, its current frontier, and its evolving thematic architecture. It therefore addresses three research questions: which cited references structure the intellectual core of airport competitiveness research, which document clusters define its current research fronts, and which latent themes dominate the literature and how have they changed during 2015–2025? By answering these questions, the study provides a more systematic and reproducible account of airport competitiveness research and clarifies directions for future work.

The remainder of the article is organized as follows. Section 2 clarifies the economic meaning of airport competitiveness by distinguishing its principal dimensions, drivers, and outcomes. Section 3 describes the data collection procedure and the methodological framework underpinning the bibliometric mapping and STM analyses. Section 4 reports the main bibliometric results, including descriptive patterns, the intellectual structure of the field, and current research fronts. Section 5 interprets the thematic structure identified by STM, Section 6 examines intertopic relations, and Section 7 traces changes in topic prevalence over time. Section 8 discusses what these results mean for airport economics and for the evolving meaning of airport competitiveness. Section 9 concludes by summarizing the answers to the research questions, acknowledging the study's limitations, and outlining directions for future research.

2. Airport competitiveness as an economic construct

Airport competitiveness should not be treated as a synonym for traffic size, isolated efficiency scores, or general airport performance. In economic terms, it is better understood as the relative capacity of an airport to attract and retain airlines, passengers, cargo flows, and commercial activity under conditions of inter-airport and intermodal rivalry. This makes competitiveness a relational and multidimensional construct: it depends not only on internal productivity, but also on network position, market access, regulatory setting, and the ability to convert these conditions into durable strategic advantage. Prior work already points in this direction by linking airport competitiveness to dynamic capability formation, governance arrangements, pricing, and spatial competition rather than to a single output indicator (Cui et al., 2013; Oum et al., 2008; Adler & Liebert, 2014).

2.1. Dimensions of airport competitiveness

The first analytical layer concerns the dimensions through which competitiveness is expressed. One dimension is productive and operational efficiency, usually captured through DEA, SFA, or productivity-based benchmarking, where airports are evaluated according to how effectively they transform infrastructure, labor, and capital into passenger, cargo, and aircraft-movement outputs (Barros & Dieke, 2007; Adler & Liebert, 2014). A second dimension is market and network positioning, reflected in accessibility, route structure, hub status, and centrality within wider air transport systems (Cheung et al., 2020; Güner et al., 2024). A third dimension is spatial and strategic attractiveness, meaning the airport's ability to compete within multi-airport regions, to integrate with high-speed rail and other modes, and to secure demand from overlapping catchment areas (Pels et al., 2003; Chen et al., 2022; Bergantino et al., 2021). A fourth dimension concerns adaptive competitiveness, that is, the capacity to remain viable under environmental, technological, and regulatory change, including pressures related to sustainability, decarbonization, and non-aeronautical revenue models (Karanki, 2025; Ngo et al., 2025).

2.2. Drivers of airport competitiveness

These dimensions are shaped by a distinct set of drivers. Some are internal and managerial: ownership form, governance quality, pricing strategy, capacity management, commercial diversification, and technological capability. Others are structural and external: catchment size and income, metropolitan hierarchy, airline network strategies, regulatory constraints, and intermodal accessibility. The distinction is important because airports do not compete under equal initial conditions. Part of their competitive position is produced inside the organization, but part is inherited from the territorial and institutional environment in which they operate. Empirical studies repeatedly show that ownership and regulation affect efficiency, that spatial dependence matters in multi-airport systems, and that connectivity advantages can reinforce cumulative gains over time (Oum et al., 2008; Karanki & Lim, 2023; Hu et al., 2023).

2.3. Outcomes of airport competitiveness

Outcomes should therefore be distinguished from both dimensions and drivers. Economically, competitive success becomes observable in the airport's realized position: stronger traffic retention or growth, broader route portfolios, higher productivity or profitability, greater resilience to shocks, improved network centrality, and, in some cases, wider regional spillovers. This distinction is not trivial. Efficiency scores, for example, are often used as proxies for competitiveness, but they are more precisely indicators of one dimension of competitiveness rather than the construct in its entirety. Likewise, centrality may function both as an explanatory condition and as an outcome of successful strategic positioning. Analytical clarity therefore

requires the article to treat airport competitiveness as a layered construct in which dimensions describe what competitiveness consists of, drivers explain what shapes it, and outcomes reveal what it produces (Cheung et al., 2020; Güner & Codal, 2024; Karanki, 2025).

This distinction is important for the bibliometric analysis that follows. The reviewed literature does not speak with one voice: some studies operationalize competitiveness through efficiency, others through accessibility, spatial rivalry, governance, sustainability, or network advantage. Rather than collapsing these approaches into a single metric, the article treats them as different analytical entry points into the economics of airport competition. This conceptual clarification provides the basis for the subsequent data and methodology section and helps explain why the mapped field contains both benchmarking studies and work focused on market structure, connectivity, and strategic adaptation.

Table 1. Conceptual dimensions, drivers, and outcomes of airport competitiveness

Dimensions	Drivers	Outcomes
Operational efficiency and reliability	Governance quality, managerial capability, process organization	Lower costs and stable service continuity
Connectivity and market accessibility	Catchment size, intermodality, airline portfolio, slot capacity	Traffic growth, route retention, and wider market reach
Commercial attractiveness	Pricing strategy, commercial mix, infrastructure quality, digitalization	Aeronautical and non-aeronautical revenue growth
Environmental and resilience capability	Regulation, sustainability investments, stakeholder coordination	Resilience and long-run strategic position

Source: Authors' elaboration.

3. Data and methodology

3.1. Data collection and corpus construction

The bibliographic corpus was assembled from the Web of Science Core Collection. The search was executed and exported on 9 March 2026. A reproducible equivalent of the smart-search protocol can be written as: TS=((airport AND competitiv*) OR “airport competition” OR “airport competitiveness” OR “airport efficiency” OR „airport performance”) NOT TS=(“airline competition” OR “airline industry” OR airlines OR “airport service quality” OR “full-service carriers” OR “low-cost carriers” OR “passenger experience”). The retrieval was restricted to publication years 2015–2025 and to document types relevant for scholarly synthesis,

namely articles, proceedings papers, review articles, book chapters, and early-access items.

No language filter was imposed at retrieval. The final corpus is therefore multilingual, although overwhelmingly English-language (288 of 303 records). The initial search returned 433 records. Titles, abstracts, author keywords, and Keywords Plus were then screened and coded as Keep, Exclude, or Review. This produced 309 retained records, 93 exclusions, and 31 review cases. To align the analytical window with the article's stated period, six records indexed as 2026 were removed from the retained set, yielding a final corpus of 303 publications. The text-mining input for each document was constructed by concatenating the title, abstract, author keywords, and Keywords Plus fields.

Table 2. Replicable retrieval protocol and corpus construction

Parameter	Specification
Source database	Web of Science Core Collection.
Search/export date	9 March 2026.
Equivalent Boolean search string	TS=((airport AND competitiv*) OR "airport competition" OR "airport competitiveness" OR "airport efficiency" OR "airport performance") NOT TS=("airline competition" OR "airline industry" OR airlines OR "airport service quality" OR "full-service carriers" OR "low-cost carriers" OR "passenger experience").
Filters	Publication years: 2015–2025. Document types: Article, Proceedings Paper, Review Article, Book Chapter, Early Access.
Language	No language filter at retrieval; final corpus: 288 English-language records and 15 records in other languages.
Workflow	433 initial records -> 309 retained after screening -> minus 6 records indexed as 2026 -> 303 final records.
Text fields used in topic modelling	Title, abstract, author keywords, and Keywords Plus.

Source: Authors' elaboration based on the Web of Science Core Collection and the filtered corpus.

3.2. Bibliometric mapping

The methodological design combines descriptive bibliometrics, relational science mapping, and topic modelling. Descriptive statistics were used to characterize annual output, document-format composition, source concentration, and language distribution. The science-mapping component was implemented in VOSviewer. Full counting was used throughout, meaning that each observed co-citation relation and each shared-reference relation contributed one full unit to the corresponding link

strength. Network layout relied on association-strength normalization, which is the default and recommended normalization in VOSviewer because it reduces the distorting effect of highly cited items and produces distances that are easier to interpret as relative similarity (van Eck & Waltman, 2010; Waltman et al., 2010).

To reconstruct the field's intellectual structure, the study estimated a cited-reference co-citation network. If $c_{dr} = 1$ when document d cites reference r and 0 otherwise, the co-citation strength between references r and s is $c_{rs} = \sum_d c_{dr} c_{ds}$. Co-citation analysis is retrospective: it identifies earlier works that are repeatedly mobilized together and therefore constitute part of the field's canonical knowledge base (Small, 1973). The co-citation map retained references with at least 20 co-citations. This threshold was selected for two reasons. First, lower cut-offs produced a visually saturated network dominated by weak and infrequently repeated links. Second, the 20-citation threshold reduced 11,218 cited references to a compact core of 26 items, which is stringent enough to isolate the canonical base while still preserving cluster connectivity and substantive interpretability.

Current research fronts were examined through bibliographic coupling at the document level, where b_{ij} for documents i and j with reference sets R_i and R_j (Kessler, 1963). Unlike co-citation, bibliographic coupling is prospective or contemporaneous: it groups recent works that rely on similar reference portfolios and therefore captures active lines of development. The full 303-document coupling network is densely connected. For visualization, the map was therefore restricted to the 50 documents with the highest number of links. This cut-off was chosen to preserve readability and to focus the graph on the dense frontier of the field rather than on weak peripheral ties. In the VOSviewer maps, node size indicates relative prominence, link thickness indicates relation strength, and colors denote algorithmically detected clusters.

3.3. Structural Topic Modeling

Bibliometric mapping was complemented with topic modelling to recover the latent semantic organization of the corpus and to examine how topical emphasis changes over time. Following the logic of Structural Topic Modeling (Roberts et al., 2014; Roberts et al., 2019), the analytical workflow treated documents as mixtures of topics and topics as probability distributions over words, while publication year was retained as the key temporal covariate for interpreting prevalence trends. Text preprocessing was standardized before estimation: all text was lowercased; punctuation, numerals, and routine stop words were removed; and the textual representation of each document was built by concatenating titles, abstracts, author keywords, and Keywords Plus. Terms appearing in fewer than four documents were dropped as rare terms, and very common terms appearing in more than 85% of documents were also removed. The screening workflow was run with a fixed random seed of 42 in Python 3.13 using scikit-learn 1.8.0 for document-term construction and diagnostic comparison across candidate models.

Because no single statistic identifies an unquestionable optimum, candidate solutions from $K = 3$ to 20 were compared jointly using held-out log likelihood, perplexity, semantic coherence, exclusivity, and substantive interpretability. Table 3 reports the diagnostic profile. Lower- K specifications achieved better raw statistical fit, but they collapsed conceptually distinct strands that the article seeks to distinguish, especially benchmarking, intermodal accessibility, data-driven operations, sustainability and risk, hydrogen transition, and airport-led development. The six-topic solution was therefore retained as the first specification that provided a workable balance between statistical adequacy and substantive separability. Importantly, the word clouds reported later in the article are model-based rather than frequency-based: they visualize the estimated topic-word salience within each topic. For additional transparency, Table 4 reports the retained topic labels, their top words, and representative documents that guided topic interpretation.

Table 3. Diagnostic profile of candidate topic solutions ($K = 3$ –20)

K	Held-out log likelihood	Perplexity	Semantic coherence	Exclusivity
3	-51179.9	2079.6	-0.807	0.643
4	-52360.9	2480.5	-0.986	0.599
5	-53636.7	3000.9	-1.178	0.565
6	-54716.3	3525.7	-1.234	0.523
7	-55733.5	4103.8	-1.321	0.480
8	-56691.1	4734.5	-1.269	0.472
9	-57769.4	5561.3	-1.277	0.434
10	-58681.1	6372.1	-1.268	0.400
11	-59524.0	7226.4	-1.253	0.381
12	-60367.2	8195.8	-1.189	0.382
13	-60705.2	8619.9	-1.299	0.365
14	-61501.4	9707.8	-1.355	0.392
15	-62481.9	11237.9	-1.362	0.365
16	-63951.4	13994.3	-1.359	0.320
17	-64970.3	16293.3	-1.349	0.316
18	-65569.5	17817.7	-1.406	0.300
19	-66493.8	20454.0	-1.325	0.283
20	-67375.0	23329.5	-1.345	0.285

Source: Authors' calculations based on the filtered corpus ($n = 303$).

Table 4. Retained topic labels, top words, and representative documents in the six-topic solution.

Topic	Label	Top words	Representative documents
1	Airport-led urban and regional development	infrastructure, development, urban, construction, projects, port, private, indonesia	2018 – Pavement Technology and Airport Infrastructure Expansion Impact; 2018 – The Impact of Airport Performance towards Construction and Infrastructure Expansion in Indonesia; 2015 – The Dube TradePort-King Shaka International Airport mega-project: Exploring impacts in the context of multi-scalar governance processes
2	Accessibility, intermodal competition, and passenger connectivity	air, transport, network, connectivity, passenger, accessibility, airports, competition	2020 – GEOGRAPHIC PERSPECTIVE OF AIR CONNECTIVITY DEVELOPMENT IN COLOMBIA; 2022 – Network assessment of Tier-II Indian cities' airports in terms of type, accessibility, and connectivity; 2018 – The potential short-term impact of a Hyperloop service between San Francisco and Los Angeles on airport competition in California
3	Hydrogen-based decarbonization and energy transition	hydrogen, energy, production, fuel, aviation, fuels, green, aircraft	2024 – Challenges of Decarbonizing Aviation via Hydrogen Propulsion: Technology Performance Targets and Energy System Trade-Offs; 2025 – Strategies for decarbonizing the aviation sector: Evaluating economic competitiveness of green hydrogen value chains- A case study in France; 2023 – H2-powered aviation – Design and economics of green LH2 supply for airports
4	Efficiency and productivity benchmarking	efficiency, airports, dea, analysis, envelopment, data, productivity, performance	2019 – Assessment of efficiency in privatized airports; 2019 – A hybrid AHP/DEA-AR model for measuring and comparing the efficiency of airports; 2019 – Performance measurement of airports using data envelopment analysis: A review of methods and findings

continued Table 4

5	Strategic sustainability, risk, and knowledge management	performance, management, sustainability, environmental, risk, airports, sustainable, study	2022 – Assortment of Airports' Sustainability Strategy: A Comprehensiveness Analysis Framework; 2022 – Airports' Sustainability Strategy: Evaluation Framework Upon Environmental Awareness; 2021 – A SOFTWARE DEVELOPMENT APPLICATION FOR SUSTAINABLE AIRPORT PERFORMANCE ANALYSIS
6	Intelligent delay analytics and ground-operation optimization	aircraft, time, algorithm, traffic, flight, prediction, learning, simulation	2022 – Physics-Based Learning for Aircraft Waiting Time Prediction; 2021 – Implementation of a Long-Range Air Traffic Flow Management for the Asia-Pacific Region; 2024 –Modified imperialist competitive algorithm for aircraft landing scheduling problem

Source: Authors' calculations based on the filtered corpus (n = 303).

4. Results

4.1. Corpus Characteristics and Publication Trends

Figure 1 reports the annual distribution of publications in the final corpus. The final corpus comprises 303 publications indexed between 2015 and 2025. Its annual distribution shows cumulative growth rather than episodic attention. Output increased from 18 items in 2015 to 40 in 2020 and then stabilized at an elevated level, remaining between 23 and 33 publications per year in 2021–2025.

This pattern indicates that airport competitiveness has evolved from a relatively specialized topic into a durable research stream with stable scholarly demand. The compositional structure of the corpus points in the same direction. Article-based formats dominate the sample, with 249 records containing an article designation, while proceedings papers account for 49 items and stand-alone reviews remain limited to five. The source structure is concentrated but not monopolized. Journal of Air Transport Management contributes 38 publications, followed by Transport Policy with 15 and Research in Transportation Business and Management with 9. This distribution confirms that the field is anchored mainly in transport economics, policy, and management journals, while still drawing selectively on neighboring outlets concerned with sustainability, geography, and operations research. Taken together, the time profile, document mix, and source concentration suggest a field that has reached institutional maturity but continues to diversify methodologically and substantively.

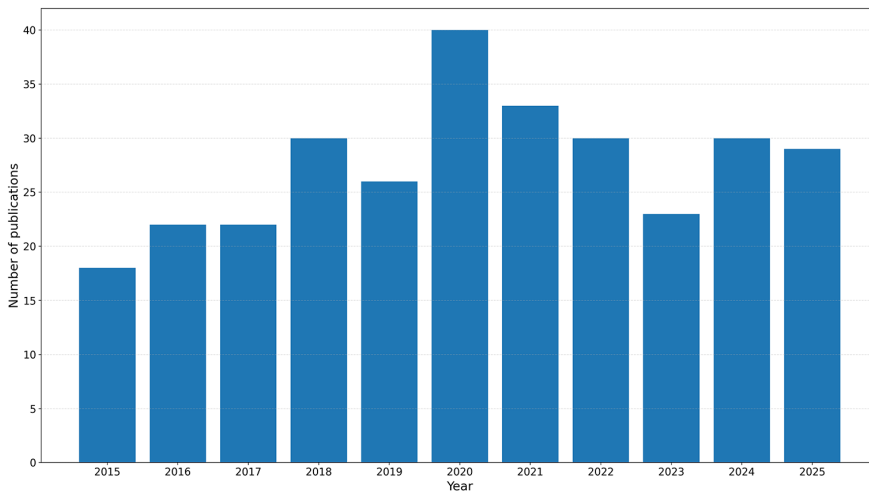


Figure 1. Annual distribution of publications in airport competitiveness research, 2015–2025
Source: Authors' elaboration based on the filtered Web of Science Core Collection corpus (n = 303).

4.2. Intellectual structure of the field

Figure 2 presents the co-citation map of the field's intellectual core. Based on a minimum threshold of 20 co-citations, the map retained only 26 items out of 11,218 cited references.

This strong reduction is substantively informative: it shows that airport competitiveness research draws on a wide and heterogeneous reference universe, but that this universe is organized by a much smaller canonical base. The largest and most central nodes are Charnes et al. (1978) and Banker et al. (1984), which confirms that the field's shared intellectual language is rooted in DEA and comparative performance evaluation. Around that methodological nucleus, the map links airport-specific benchmarking applications, governance- and productivity-oriented studies, and market-access contributions. The resulting structure suggests that the field is intellectually cohesive, but cohesive mainly because a common evaluative toolkit connects otherwise heterogeneous substantive questions. Table 5 summarizes the representative references used to interpret the main strands visible in the map.

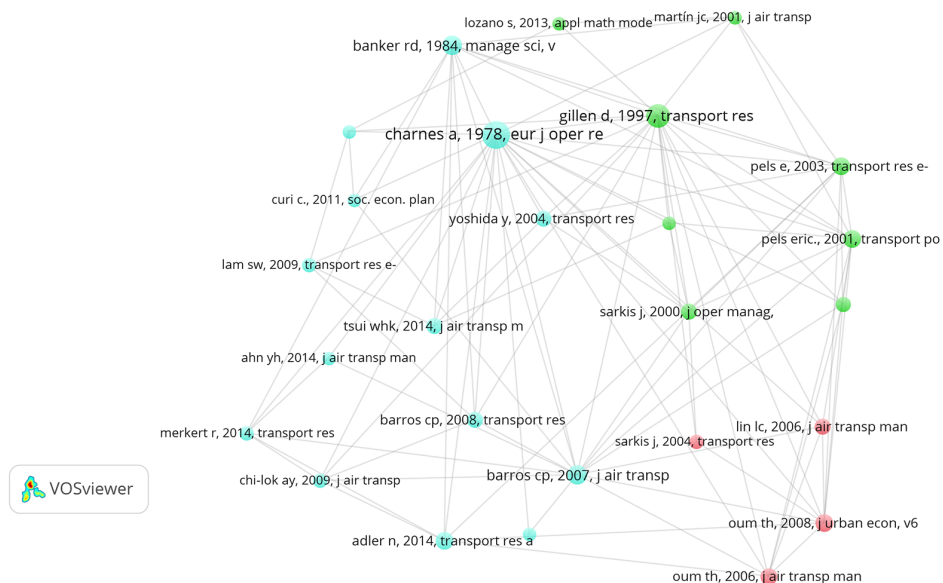


Figure 2. Co-citation map of the intellectual structure of airport competitiveness research
Source: Authors’ elaboration in VOSviewer based on cited references extracted from the filtered Web of Science Core Collection corpus.

Table 5. Representative references used to interpret the co-citation map

Reference	Year	Cluster	Main role in the map
Charnes et al.	1978	DEA methodological core	Foundational efficiency model underpinning comparative airport evaluation.
Banker et al.	1984	DEA methodological core	Variable-returns-to-scale extension that broadened the benchmarking toolkit.
Barros & Dieke	2007	Airport benchmarking	Airport-specific DEA application linking efficiency evaluation to operational evidence.
Yoshida & Fujimoto	2004	Airport benchmarking	Benchmarking study combining DEA and TFP logic in airport performance analysis.
Curi et al.	2011	Airport benchmarking	Bootstrapped DEA evidence that strengthened the empirical benchmarking tradition.
Tsui et al.	2014	Airport benchmarking	Operational efficiency comparison across Asia-Pacific airports.
Ahn & Min	2014	Airport benchmarking	Multi-period DEA/Malmquist analysis linking efficiency to productivity change.

continued Table 5

Lam et al.	2009	Airport benchmarking	Regional efficiency comparison across Asia-Pacific airports.
Adler & Liebert	2014	Governance and comparative performance	Links competition, ownership, and regulation to airport performance and pricing.
Oum et al.	2008	Governance and productivity	Ownership form and regulation as explanations of airport efficiency differences.
Sarkis & Talluri	2004	Governance and productivity	Performance-based clustering and benchmarking logic relevant to airport comparison.
Pels et al.	2003	Market access and competition	Airport access and competitive interaction in a multi-airport system.

Source: Authors' elaboration based on the co-citation map shown in Figure 2.

Around this methodological core, the network first expands into an airport-benchmarking strand built around Barros and Dieke (2007), Yoshida and Fujimoto (2004), Curi et al. (2011), Tsui et al. (2014), Ahn and Min (2014), Lam et al. (2009), and Adler and Liebert (2014). These contributions translate competitiveness into measurable relations among inputs, outputs, productivity, scale, and ownership. Their close coupling to the DEA nucleus shows that comparative airport research has accumulated cumulatively and that benchmarking remains the field's most stable empirical idiom.

A second strand emphasizes governance, productivity, and managerial comparison. Here Oum et al. (2008) and Sarkis and Talluri (2004) occupy key bridging positions between the methodological core and airport-specific applications. This part of the map broadens the field from static efficiency scores to issues of ownership form, regulation, productivity change, and comparative managerial performance. The structure of the network suggests that institutional and governance questions entered the literature mainly through their measurable effects on relative airport performance.

A third strand, located on the market-access side of the map, is anchored by Pels et al. (2003) and adjacent transport-economics contributions concerned with airport choice, access conditions, and competitive interaction across airports. Its position is revealing: market competition is present, but it remains closely tethered to the benchmarking core rather than displacing it. In that sense, the map indicates that airport competitiveness has been theorized less as an autonomous market construct than as a condition observed through comparative performance, access, and positioning.

Taken together, the co-citation network reveals a field whose intellectual structure is cohesive but asymmetric. It is cohesive because the canonical references

are densely interconnected and mutually reinforcing. It is asymmetric because methodological and benchmarking works occupy more central positions than explicitly strategic or spatial studies. Airport competitiveness research has therefore developed less through grand theorization than through a robust comparative toolkit. Its strongest common denominator is methodological standardization, while its substantive plurality appears in the diverse questions that this shared evaluative infrastructure has been used to address.

4.3. Research fronts

Figure 3 presents the bibliographic-coupling map of the current research frontier. Because bibliographic coupling groups documents that rely on similar reference portfolios, it captures active lines of development more directly than co-citation. For readability, the visualization was restricted to the 50 documents with the highest number of links. The updated map reveals three core fronts and one smaller adjacent line: a broad benchmarking complex, spatial competition and spillovers, connectivity and network position, and a peripheral set of studies on regional-airport heterogeneity and business differentiation. This pattern suggests that the frontier is not simply larger than the canonical core; it is also more internally differentiated. Table 6 summarizes the representative documents used to interpret the main visible fronts.

The largest research front is a broad benchmarking complex, but it is now internally differentiated. One part clusters advanced efficiency and productivity modelling, represented by Yu (2023), Pacagnella Junior et al. (2020), Kaya et al. (2022), and Pehlivanli and Özsoy (2025). A closely related segment extends the same comparative logic toward sustainable and context-sensitive performance evaluation, as shown for example by Cifuentes-Faura and Faura-Martínez (2023) and Ngo et al. (2025). Taken together, these studies move beyond conventional single-stage DEA toward two-stage, network, bootstrap, dynamic, and hybrid designs. Methodological refinement therefore remains the dominant way in which competitiveness is currently specified, decomposed, and contextualized.

A second front links competitiveness to spatial interaction and strategic behavior in multi-airport systems. Bergantino et al. (2021), Qian et al. (2022), Hu et al. (2023), and Karanki and Lim (2023) occupy key positions here, while Karanki (2025) extends the discussion toward capacity strategy and non-aeronautical revenues. What unites this front is a move away from the isolated airport as the default unit of analysis. Competitiveness is instead treated as relational, territorially interdependent, and shaped by spillovers, market overlap, and neighboring strategic choices.

Table 6. Representative documents used to interpret the bibliographic-coupling map

Document	Year	Research front	Main contribution
Yu	2023	Advanced efficiency modelling	Review article consolidating airport performance and benchmarking approaches.
Pacagnella Junior et al.	2020	Advanced efficiency modelling	Two-stage DEA and Malmquist approach for airport efficiency decomposition.
Kaya et al.	2022	Advanced efficiency modelling	Integrated methodology for evaluating airport efficiency in Turkey.
Pehlivanli & Özsoy	2025	Advanced efficiency modelling	Two-phase network DEA approach extending the benchmarking frontier.
Bergantino et al.	2021	Spatial competition and spillovers	Spatial stochastic frontier analysis of airport competition.
Qian et al.	2022	Spatial competition and spillovers	Estimate of spatial spillovers in airport operational efficiency.
Hu et al.	2023	Spatial competition and spillovers	Green-efficiency perspective on cumulative advantage in multi-airport systems.
Karanki & Lim	2023	Spatial competition and spillovers	Evidence on spatial dependence and competition among U.S. airports.
Cheung et al.	2020	Connectivity and network position	Global airport connectivity index and network-evolution perspective.
Chen et al.	2022	Connectivity and network position	Interaction between aviation and high-speed rail in multi-airport regions.
Güner et al.	2024	Connectivity and network position	Network centrality as an explanatory component of airport efficiency.
Pauwels et al.	2025	Regional airport differentiation	Cluster-based view of heterogeneity among regional airports and their competitive models.

Source: Authors' elaboration based on the bibliographic-coupling map shown in Figure 3.

A third front focuses on connectivity, network centrality, and intermodal structure. Cheung et al. (2020), Zhu et al. (2019), Chen et al. (2022), and Güner et al. (2024) show that competitiveness is increasingly recast in topological terms: an airport's position within aviation and multimodal networks matters alongside internal productivity and local demand. High-speed rail interaction, connectivity radiations, and centrality measures broaden the field from cost-output comparison toward relational reach and systemic embeddedness.

The updated map also shows a smaller adjacent line, visible at the lower edge of the network, around regional-airport differentiation and business-model diversity. Pauwels et al. (2025) is the clearest marker of this development, and its position at the interface between the benchmarking complex and the wider frontier suggests that future research may increasingly distinguish among different competitive archetypes rather than treat airports as a single class of organizations. Overall, the coupling structure indicates a frontier that is more integrated than the older canon but also more differentiated internally, combining performance models, spatial competition, network position, and emerging segmentation logics.

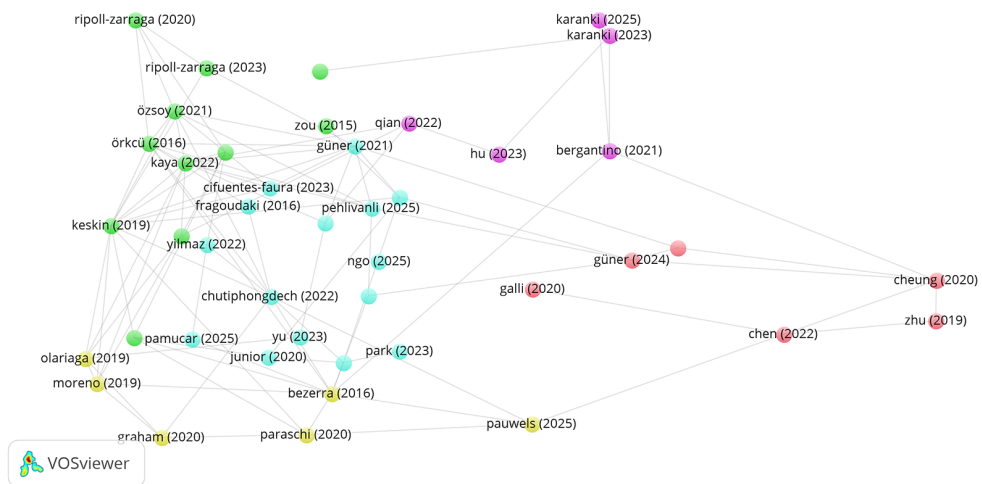


Figure 3. Bibliographic coupling map of current research fronts in airport competitiveness research

Source: Authors' elaboration in VOSviewer based on the 50 documents with the highest number of links in the filtered corpus.

5. Thematic structure of the literature

Figure 4 visualizes the six-topic STM solution through six model-based word clouds. Each cloud is derived from the estimated topic-word distribution rather than from raw frequency counts in the corpus. Consequently, word size reflects within-topic salience: the more prominent the label, the more strongly the model associates that term with the latent topic. For interpretive clarity, the discussion below uses descriptive labels rather than numeric placeholders: airport-led urban and regional development; accessibility, intermodal competition, and passenger connectivity; hydrogen-based decarbonization and energy transition; efficiency and productivity benchmarking; strategic sustainability, risk, and knowledge management; and

intelligent delay analytics and ground-operation optimization. Table 4 complements the word clouds by reporting the top words and representative documents used in topic labeling. The solution shows that airport competitiveness is studied as a multidimensional concept spanning territorial growth, network access, environmental transition, benchmarking, managerial capability, and real-time operational control.

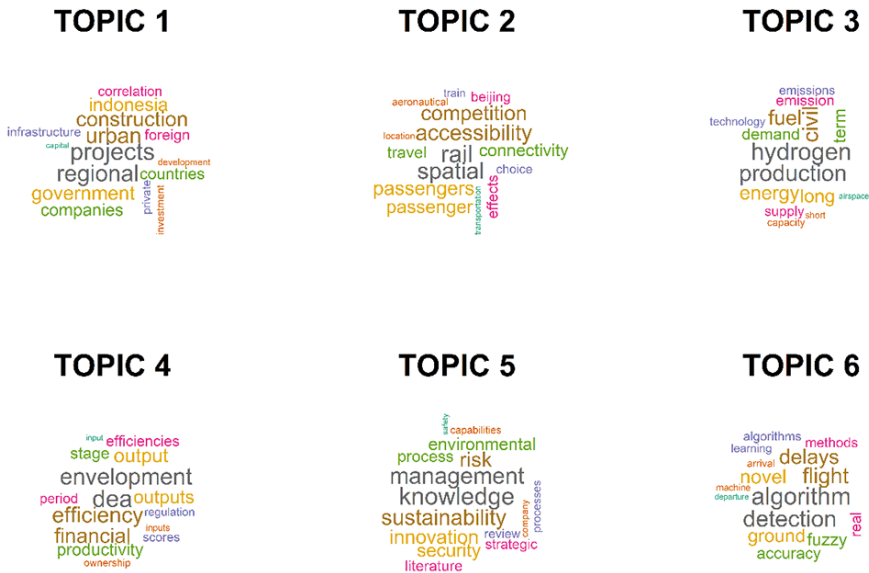


Figure 4. Model-based word clouds for the six-topic STM solution

Source: Authors' elaboration based on structural topic modeling of titles, abstracts, author keywords, and Keywords Plus.

The first theme, airport-led urban and regional development, treats the airport as a growth pole rather than merely a transport node. Salient terms such as urban, construction, projects, regions, government, companies, and investment point to a literature focused on infrastructure expansion, public-private coordination, and the territorial effects of airport development. In this stream, competitiveness is associated with the airport's ability to attract capital, reshape land use, and embed itself in wider regional development strategies.

Accessibility, intermodal competition, and passenger connectivity shifts the focus from airport-internal performance to the wider mobility system in which the airport operates. Terms such as accessibility, rail, connectivity, spatial, passengers, travel, choice, and competition indicate a demand-side perspective centered on catchment areas, modal substitution, and the comparative convenience of different transport options. Here competitiveness depends on how easily users can reach the

airport, how effectively the airport is integrated into regional transport networks, and how it performs relative to competing modes, especially high-speed rail.

Hydrogen-based decarbonization and energy transition is the clearest future-oriented theme in the model. Its vocabulary – hydrogen, production, energy, demand, fuel, emissions, supply, technology, and capacity – points to a literature in which airports are increasingly viewed as energy nodes within a wider decarbonization system. Competitiveness in this stream is linked to infrastructure readiness, access to low-carbon energy, storage and supply-chain capacity, and the techno-economic feasibility of alternative fuels.

Efficiency and productivity benchmarking represents the classical quantitative core of the field. The dominance of terms such as DEA, envelopment, outputs, efficiency, productivity, inputs, financial, scores, and ownership leaves little doubt that this topic captures the benchmarking tradition in airport research. In this literature, competitiveness is typically operationalized as relative efficiency: the capacity to transform inputs into desirable outputs under given market and institutional conditions. It is also one of the most methodologically consolidated themes in the corpus.

Strategic sustainability, risk, and knowledge management introduces a more managerial and integrative perspective. Terms such as management, knowledge, sustainability, innovation, security, risk, strategic, and environmental suggest research concerned with organizational capability, resilience, learning, and the coordination of multiple objectives. In this cluster, competitiveness is framed as an airport's capacity to manage complexity, align sustainability with strategy, incorporate innovation, and cope with uncertainty.

Intelligent delay analytics and ground-operation optimization reflects the growing influence of data-intensive and algorithmic methods in airport research. Its terms - delays, flight, algorithm, detection, ground, fuzzy, accuracy, model, arrival, departure, and machine - point to a process-level literature focused on prediction, disruption management, turnaround performance, and operational bottlenecks. Competitiveness in this stream is tied to reliability, punctuality, and the ability to improve resource use through real-time or near-real-time analytics.

Taken together, the six topics show a field that is broad rather than methodologically uniform. Two long-standing pillars remain central: spatial accessibility and efficiency benchmarking. At the same time, the model makes clear that airport competitiveness is now increasingly discussed through sustainability transition, strategic management, and data-driven operations. Competitiveness is therefore no longer defined only by traffic, scale, or cost efficiency, but also by environmental adaptation, organizational capability, and operational intelligence.

The six topics also differ in maturity and methodological consolidation. Accessibility and efficiency benchmarking represent established streams with stable vocabularies and recognizable empirical traditions. By contrast, hydrogen-based decarbonization and intelligent delay analytics are more recent and future-oriented,

driven by the twin pressures of environmental transition and digitalization. Strategic sustainability occupies an intermediate position, translating broad organizational concerns into competitiveness language. The field is therefore expanding by accumulation rather than replacement: older cores persist while newer agendas are added through technological and policy change.

6. Intertopic relations

Figure 5 reports the intertopic correlation matrix for the six-topic STM solution. All off-diagonal coefficients are negative, ranging from -0.10 to -0.29 . In substantive terms, this indicates that the thematic structure of the literature is differentiated rather than strongly overlapping: documents are more likely to be dominated by one or two leading orientations than by an even mixture of all topics. At the same time, the magnitude of the coefficients remains moderate. The matrix therefore points to structured separation, not deep fragmentation.

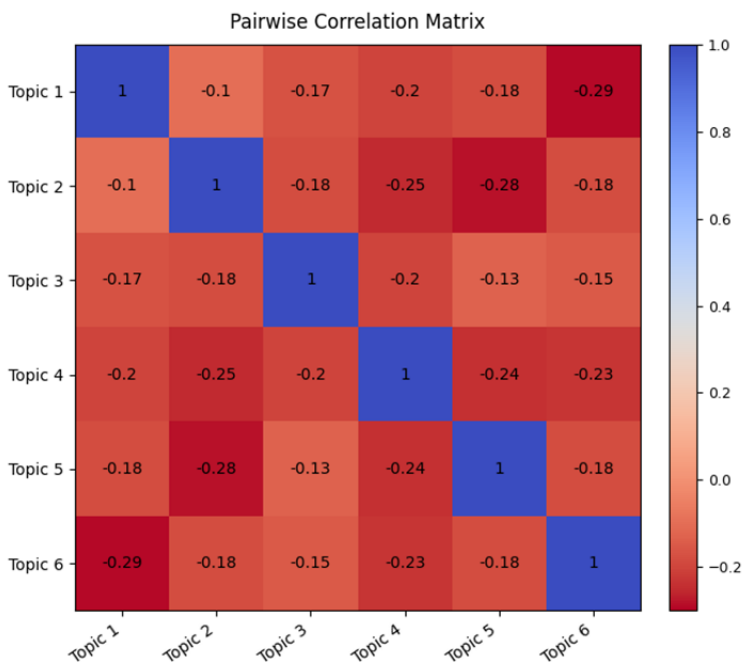


Figure 5. Intertopic correlation matrix for the six-topic STM solution

Source: Authors' elaboration based on structural topic modeling estimates.

This pattern should be read with methodological caution. In STM, negative correlations can partly reflect the compositional nature of topic prevalence estimates: when one topic becomes more prominent in a document, the relative share of other

topics must decline. The coefficients should therefore not be interpreted as evidence of conceptual incompatibility. A more appropriate reading is that the topics compete for salience within the same textual space, and that the relative magnitude of the coefficients is more informative than the sign alone.

The weakest negative relationship is observed between airport-led urban and regional development and accessibility, intermodal competition, and passenger connectivity (-0.10). This is the closest thematic pairing in the model and suggests a shared concern with the spatial positioning of airports within wider regional systems. It also indicates that territorial development and passenger access are adjacent rather than isolated ways of conceptualizing airport competitiveness.

Another relatively close set of relationships links hydrogen-based decarbonization and energy transition with strategic sustainability, risk, and knowledge management (-0.13) and with intelligent delay analytics and ground-operation optimization (-0.15). These weaker separations suggest that the transition agenda is not isolated; rather, it sits near both managerial and operational debates.

This connective role becomes clearer when the hydrogen topic is viewed across the whole matrix. Its distances from airport-led urban and regional development (-0.17) and accessibility, intermodal competition, and passenger connectivity (-0.18) are also only moderate. Compared with the remaining topics, it is less sharply separated from the rest of the model and therefore occupies an intermediate position in the thematic architecture. A useful additional inference is that decarbonization is becoming a bridging domain through which infrastructural, managerial, and technological concerns increasingly meet.

At the opposite end of the matrix, the greatest thematic distance is observed between airport-led urban and regional development and intelligent delay analytics and ground-operation optimization (-0.29). This is followed by the distance between accessibility, intermodal competition, and passenger connectivity and strategic sustainability, risk, and knowledge management (-0.28), and then between accessibility, intermodal competition, and passenger connectivity and efficiency and productivity benchmarking (-0.25). These pairings define the outer limits of the thematic space.

The relative separation of accessibility from both managerial sustainability and benchmarking is especially revealing. It suggests that passenger-side competition and airport-internal performance are still often treated as distinct analytical problems. One strand asks how airports compete within regional transport systems; the other asks how efficiently or strategically airports manage internal resources. The weak overlap between these literatures' points to an unresolved integrative gap and a promising direction for future work.

Efficiency and productivity benchmarking is likewise notable for its comparatively strong negative links with several other topics, including accessibility (-0.25), strategic sustainability (-0.24), and intelligent delay analytics (-0.23). This indicates that the benchmarking stream remains one of the most self-contained components of

the field, with a clear methodological identity and weaker overlap with surrounding themes. Overall, the matrix supports the validity of the six-topic solution and portrays airport competitiveness research as plural, moderately integrated, and internally differentiated rather than unified around a single dominant paradigm.

7. Evolution of topics over time

Figure 6 plots estimated topic prevalence over time and reveals a clear rebalancing of the field. The six themes do not move in parallel. Instead, the literature shifts from territorially oriented and broad managerial concerns toward digital operations, energy transition, and a renewed emphasis on formal performance evaluation. The temporal pattern therefore complements the static topic map by showing which strands are losing prominence, which remain stable, and which are becoming more central to the contemporary research agenda.

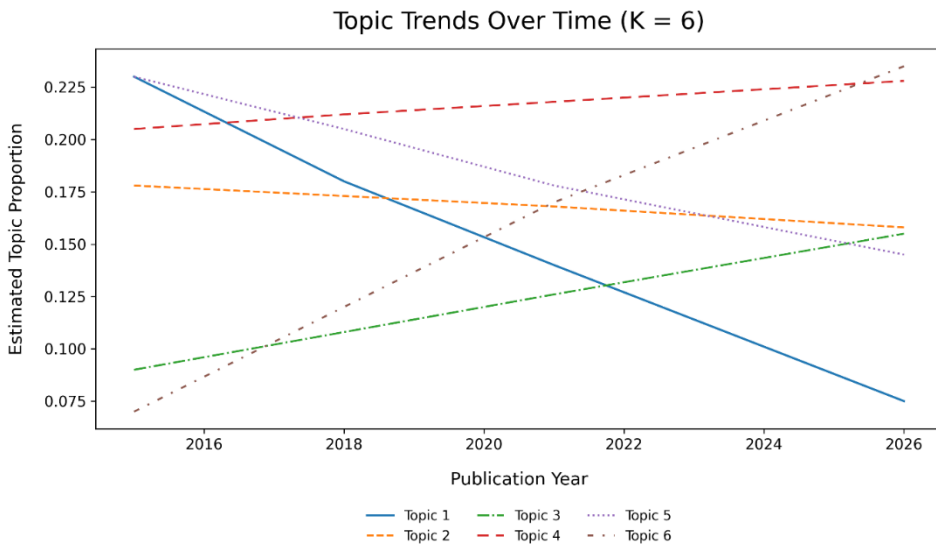


Figure 6. Estimated topic prevalence over time in the six-topic STM solution

Source: Authors' elaboration based on structural topic modeling estimates with publication year included as the prevalence covariate.

The sharpest decline is observed in airport-led urban and regional development. It begins as one of the most prominent topics but steadily loses prevalence and becomes the weakest theme by the end of the period. This suggests that macro-developmental narratives, although still present, no longer organize the field to the same degree as in the earlier years of the sample. Strategic sustainability, risk, and knowledge management also declines from a high starting point, but more

gradually. Accessibility, intermodal competition, and passenger connectivity shows only a modest downward slope, which indicates that passenger-side and network-access questions remain an enduring, if no longer expanding, core of the literature.

By contrast, intelligent delay analytics and ground-operation optimization records the strongest upward trajectory. Starting from the lowest baseline, it rises rapidly across the period and becomes the most prevalent theme at the end of the series. This is strong evidence that airport competitiveness research is increasingly oriented toward data-rich operations, prediction, and decision support. Hydrogen-based decarbonization and energy transition also grows steadily, confirming that environmental transition has moved from a peripheral concern to a central research frontier. Efficiency and productivity benchmarking rises more moderately but consistently, which suggests not the decline of classical performance analysis, but its continued relevance under new technological and policy conditions.

Several crossover points are especially informative. Around the early 2020s, intelligent delay analytics overtakes airport-led urban and regional development and later surpasses strategic sustainability as well. Hydrogen-based decarbonization also rises above airport-led development and approaches the level of accessibility toward the end of the period. These shifts indicate that the field is not only diversifying; it is also changing its center of gravity. Research attention is moving away from broad structural and regional questions toward topics that are closer to operational control, technological transition, and measurable performance.

Overall, the temporal model suggests a move from outward-facing competition – defined mainly by catchment areas, infrastructure expansion, and regional positioning – toward a more internal and systems-oriented understanding of competitiveness based on resilience, decarbonization capability, algorithmic optimization, and evidence-based management. Yet the older themes do not disappear. Accessibility remains substantial, and managerial sustainability stays visible despite its relative decline. The main conclusion is therefore not replacement but recomposition: airport competitiveness research is becoming more technologically intensive and transition-oriented while retaining its established spatial and economic foundations.

8. Discussion

The results have direct implications for the economics of airports because they show that airport competitiveness is not adequately captured by traffic volume, isolated efficiency scores, or simple market-share comparisons. The co-citation core demonstrates that the field's canonical language was built around benchmarking and performance evaluation, especially DEA-based comparison. Yet the bibliographic-coupling results and STM indicate that contemporary scholarship increasingly embeds these measures in wider spatial, network, and transition contexts. Taken together, the findings support a more economic definition of airport competitiveness as

the capacity of an airport to transform productive resources, territorial accessibility, network position, and strategic flexibility into a durable market position under inter-airport and intermodal rivalry. This reading is consistent with studies that connect airport performance to ownership, regulation, connectivity, and dynamic capability formation rather than to a single output indicator (Cui et al., 2013; Oum et al., 2008; Adler & Liebert, 2014).

The study also helps to identify where the field is already mature and where it remains fragmentary. Benchmarking and productivity analysis form the most consolidated part of the literature: they possess a stable methodological canon, recurrent empirical designs, and a clear comparative logic. Accessibility and connectivity research also shows substantial maturity, especially where airport competition is examined through catchment overlap, route structure, network centrality, and multimodal substitution (Pels et al., 2003; Cheung et al., 2020; Chen et al., 2022). The updated coupling map, however, suggests that the frontier no longer consists only of these established strands plus a generic sustainability turn. It also contains an emerging line on regional-airport heterogeneity, diversification, and differentiated competitive models. By contrast, the links between these established strands and newer agendas remain partial. The intertopic results reveal limited overlap between passenger-side competition, managerial sustainability, and internal efficiency benchmarking. Hydrogen transition and intelligent ground-operation analytics are rising rapidly, but they are not yet fully integrated into a common explanatory framework of airport competitiveness. The field is therefore mature at the level of methods and substreams, but still incomplete at the level of synthesis.

Several implications follow for governance and investment. Governance cannot be treated merely as a control variable behind efficiency scores. Because competitiveness depends on ownership form, regulatory discretion, commercial strategy, pricing capability, and coordination capacity, institutional arrangements shape an airport's ability to retain routes, diversify revenues, and respond to shocks (Oum et al., 2008; Adler & Liebert, 2014; Karanki, 2025). The findings also suggest that infrastructure expansion alone no longer constitutes a sufficient competitive strategy. Investment matters when it improves relative position: by strengthening connectivity, expanding intermodal access, enabling non-aeronautical revenue generation, or preparing the airport for decarbonization and operational resilience. In economic terms, the relevant question is no longer whether airports invest more, but whether they invest in assets and capabilities that alter their position within contested network systems.

The results likewise redefine the role of intermodality and sustainability in airport competition. Intermodality matters because airport competition increasingly extends beyond airport-against-airport rivalry to include substitution, complementarity, and coordination with high-speed rail and other modes. Accessibility is therefore not an auxiliary service characteristic; it is one of the main channels through which

airports compete for demand, especially in multi-airport regions. Sustainability also emerges here as a competitive variable rather than an external constraint. The temporal rise of hydrogen, energy-transition, and strategic-sustainability topics suggests that decarbonization capability, environmental compliance, and resilience are becoming part of long-run competitive position. For airport economics, this means that competitiveness must now be assessed jointly through productive efficiency, network embeddedness, territorial accessibility, and transition readiness.

Overall, the findings imply a shift from a narrow productivity lens toward a broader economics of positional advantage. The most promising next step is not to abandon benchmarking, but to integrate benchmarking with network analysis, territorial competition, governance design, revenue diversification, regional-airport differentiation, and transition risk. Such integration would allow the literature to explain not only which airports perform better, but also why particular competitive models become more viable under changing technological, spatial, and regulatory conditions.

9. Conclusions

This article addressed three research questions. First, it showed that the intellectual core of airport competitiveness research is structured mainly by benchmarking and efficiency-oriented references, with governance and market-access studies connected to, but secondary to, that methodological core. Second, it demonstrated that the current research frontier is organized around three core fronts—advanced efficiency modelling, spatial competition and spillovers, and connectivity- and network-based analysis—together with a smaller adjacent line focused on regional-airport heterogeneity and diversification. Third, the STM results identified six latent themes and revealed a clear temporal rebalancing of the field toward digital operations, decarbonization, and renewed performance analytics, while accessibility and benchmarking remain its enduring anchors.

The main contribution of the article is therefore both substantive and methodological. Substantively, the study redefines airport competitiveness as a layered economic construct rather than as a synonym for throughput, traffic growth, or isolated efficiency scores. Competitiveness emerges here as the ability to convert internal capabilities and external positional advantages into a durable relative market position. Methodologically, the article shows the value of combining bibliometric mapping with Structural Topic Modeling in order to reconstruct the field's canonical base, detect active research fronts, and trace the evolution of latent themes over time. This combined design offers a more systematic account of airport competitiveness research than a conventional narrative review alone.

At the same time, the study has several limitations. The corpus is restricted to the Web of Science Core Collection and to the 2015–2025 period, which means that

relevant work indexed elsewhere or published outside the selected window is not captured. The screening process, although explicit, still contains an element of informed qualitative judgment. In addition, the bibliometric maps depend on threshold choices and visualization cut-offs, while topic interpretation in STM remains partly model-dependent and sensitive to preprocessing decisions. These limitations do not invalidate the results, but they do define the scope within which the conclusions should be read.

Four directions for future research follow directly from the analysis. First, future studies should integrate efficiency, accessibility, and network centrality within common explanatory models rather than treating them as separate traditions. Second, more work is needed on how governance, ownership, pricing, and non-aeronautical revenue strategies interact with sustainability and resilience outcomes. Third, airport competition should be examined more explicitly in multi-airport and intermodal settings, with clearer distinctions between major hubs, secondary airports, and regional airports characterized by different business models. Fourth, the literature would benefit from extensions beyond Web of Science and beyond metadata-level text, including full-text corpora and post-2025 developments. Taken together, these directions point toward a more integrated theory of airport competitiveness that is at once economic, spatial, organizational, and transition-oriented.

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