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Operations Research in Airline Scheduling: A Bibliometric Analysis of Current Trends and Future Directions (2020–2026)

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ABSTRACT

This bibliometric analysis offers a comprehensive overview of the evolving landscape of Airline Scheduling research from an Operations Research (OR) perspective. The set of 500 records used in the study includes works published in 2020 through 2026, with 297 i.e. 59.4%, of them originating in 2024-2026. This suggests active ongoing research into the topic, though 2026 is obviously an incomplete year for publication. Authors have identified the breadth and fragmentation of research that is related to airline scheduling which is the origin of the motivation of the current study. The literature has been developed into several specialized problems including the three key areas of crew scheduling, fleet assignment and aircraft routing, as well as related topics such as aircraft maintenance, disruption management and delay propagation. Existing reviews as demonstrated display the depth of individual streams, (Xu et al., 2024) reviews airline scheduling optimization and modelling methodologies, while (S. Wu et al., 2025) reviews airline recovery problems under disruptions. The literature continues to rely on established OR techniques such as column generation and mathematical programming, while also incorporating newer approaches such as machine learning and reinforcement learning (Wandelt, Wang, et al., 2025; Zhang et al., 2024). The future research agenda identifies integrated multi-resource disruption recovery as the largest growing theme, followed by uncertainty-aware scheduling and predictive AI integrated with prescriptive operations research.

Keywords: crew scheduling, fleet assignment and aircraft routing, column generation, scheduling, optimization, airline operations and disruption management.

1. INTRODUCTION

Decisions concerning aircraft, routes and crew directly influence operating costs, aircraft utilization, service reliability and the airline's ability to meet passenger demand. Recent research highlights the importance of OR in the field of air transportation, where it has been contributory in enhancing efficiency, safety, cost-effectiveness and profitability. **Airline scheduling** is the process of coordinating a network of flights and allocating the resources required to operate those flights efficiently and reliably. In the literature, the term tends to be used in deciding how scarce operational resources should be assigned across a complex and interconnected network. The interdependence between the key areas makes airline scheduling a multidimensional decision problem rather than a collection of

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independent scheduling tasks. The researchers have chosen to dive into this topic for several reasons. The financial relevance of these decisions is particularly clear in crew scheduling (Cheng et al., 2026) notes that crew costs are reported to be the second-largest cost component for airlines worldwide, making efficient crew allocation important for profitability and competitiveness. Fleet decisions also have wider financial consequences (Miao et al., 2026) "fleet management is one of the most crucial components of airline operations because it affects profitability, operational efficiency and environmental sustainability. The study uses bibliometric analysis of a dataset containing 500 records retrieved using the three keywords crew scheduling, fleet assignment and aircraft routing. Bibliometric analysis is appropriate for the purpose of the research because it enables a large body of publications to be examined through measurable patterns rather than relying only on individual studies. The literature is found moving from isolated resource-specific models toward integrated, uncertainty-aware and increasingly data-driven approaches. The review also indicates that established optimization methods remain important, while machine learning and reinforcement learning are increasingly being used as complementary tools rather than straightforward alternatives for classical operations research. The findings suggest a substantial increase in publication activity across the period. The keyword patterns provide insight into the concepts receiving sustained attention. These patterns indicate the continued importance of classical optimization while also showing growing attention to disruption, uncertainty and learning-based methods. Lastly, the analysis considers thematic directions that emerge from the literature.

The article is aimed at both of these audiences. To the academic one, the existing literature presented can help identify gaps, which can be taken as subjects of further research. To the industrialists, the latest trends in scheduling of flights can be detected and analysed for potential improvements and automation in their organisations. The next section is a literature review devoted to the intricacies of our research field. Following that, the subsequent sections combine the academic and practical 5.2 IMPLICATIONS of the discoveries, leading to a concluding one, summarising what is essentially our study.

2. RESEARCH METHODOLOGY

2.1 Data Collection

We retrieved the bibliographic data from the Publish or Perish and ScienceDirect databases, which was used as the literature source for our study. The chosen database offers bibliographic records.

2.2 Research Design

We used a bibliometric research design to investigate the development, structure, and major research trends in airline scheduling and its related Operations Research. The bibliometric analysis is a quantitative study of works on a specific topic based on patterns such as the quantity of publishing, authors, sources, keywords, citations, and associations between the areas. We used bibliometric analysis to explore airline scheduling, which consists of many interrelated areas, including aircraft routing, fleet assignment and crew scheduling. We followed the procedure that consisted of the literature identification, screening, selection, and bibliometric analysis steps. Our search period was set to 2020–2026, which allowed us to explore the research on airline scheduling during the selected period.

We searched for articles published in 2020–2026 and included three main keyword areas for our analysis: Aircraft Routing, Fleet Assignment and Crew Scheduling. We applied Boolean operators to combine the keywords and find the relevant documents published in the selected period:

"Aircraft Routing" OR "Fleet Assignment" OR "Crew Scheduling" AND "Operations Research"

The search result of 1072 items was retrieved for our initial bibliometric analysis of airline scheduling.

2.3 Screening and Selection of Publications

After performing our initial search in Publish or Perish and ScienceDirect, we proceeded to screen the records to identify the publications relevant to our investigation. The screening process was visualized in a PRISMA

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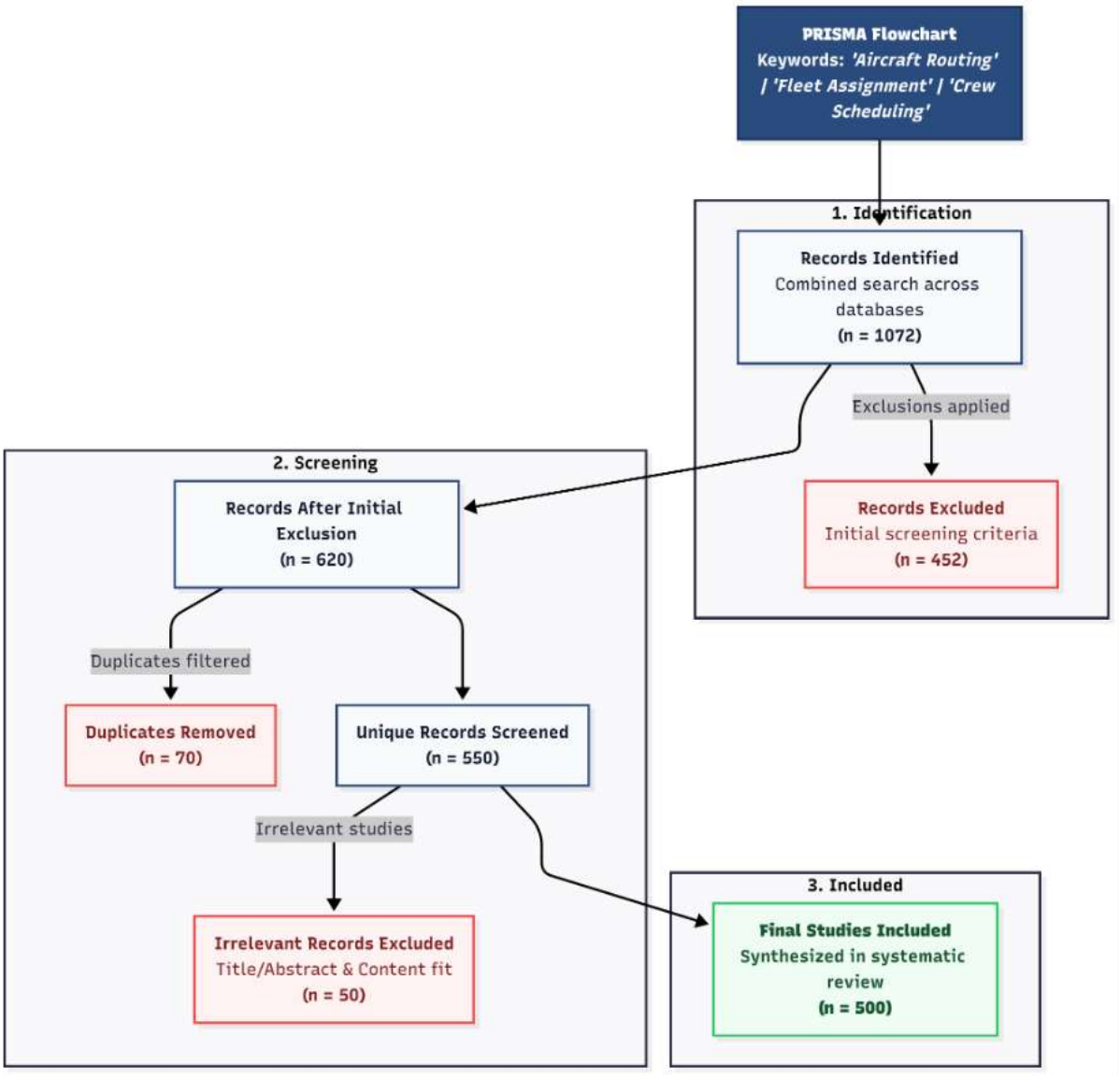
flowchart that consisted of the identification, exclusion, duplicate removal, relevance screening, and selection stages.

The first stage of the screening process involved the removal of the items that did not correspond to the inclusion criteria. We excluded the non-English publications, conference papers, books, and book chapters, and thus refined the record set from 1072 to 620 items.

The next step involved the duplicate removal to ensure that the same publication was not included in the final dataset more than once. As a result, 550 items were left in the analyzed record set. After that, we performed the relevance screening to exclude the manuscripts that did not correspond to the purpose of our research. As a result, 50 irrelevant or out-of-scope items were removed from the dataset.

Consequently, 500 papers were included in our bibliometric analysis of airline scheduling. Therefore, the screening process followed by the data removal steps was applied to the initial record set of 1072 items. As a result, we obtained the final paper set of 500 items that were included in our analysis.



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2.4 Data Processing

We proceeded to compile the selected bibliography into the dataset and prepared it for the analysis. We employed RStudio as our working environment and Bibliometrix and Biblioshiny as the tools for processing and analyzing the bibliographic data. Biblioshiny is a graphical interface that allows the users to perform bibliometric analysis and visualize the research data. We started the analysis by importing the selected bibliography into Biblioshiny and exploring the information before proceeding to the analysis. Data processing and verification was crucial since the quality of the dataset determined the analysis that could be performed**.**

2.5 Bibliometric Analysis

Using Biblioshiny in RStudio, we analysed the final dataset consisting of 500 papers in terms of annual scientific production, thematic evolution, keyword analysis, author productivity, source and journal analysis, and discipline life-cycle analysis. The trends in the scientific production were determined, the changes in research themes and keywords were identified, the patterns of authors and journals productivity were examined, and the research on airline scheduling was analysed.

3. LITERATURE REVIEW

3.1 Conceptual Background

Airline scheduling research is commonly split into three stages that happen one after another. The first stage, fleet assignment, matches an aircraft to a scheduled flight leg. The second stage, aircraft routing, follows each tail number through a set of legs, over the planning horizon. The third stage, crew scheduling, pairs and rosters flight crew to cover those legs.

3.2 Frequent Terms in Airline Scheduling:

Term	What it means
Fleet assignment	In order to achieve profit maximisation, fleet assignment connects aircrafts to flight legs within the airline's network. When addressing this problem, constraints on passenger demand and fleet arrangement must be considered. (Ben Ahmed et al., 2022)
Crew Scheduling	Crew scheduling is a low cost solution for allocating crew to each flight while complying to rules and contractual obligations. (Khanmirza et al., 2020)
Aircraft routing	It is the act of selecting the order in which a specific aircraft will fly. (Birolini & Jacquillat, 2023)
Robust Scheduling	Creating a cushion or schedule slack to allow a plan to smoothly decline in the event of a disruption. (Akıncılar & Güner, 2025)
Matheuristic	It's a hybrid technique that combines heuristic search and explicit mathematical programming. (Ben Ahmed et al., 2022)

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3.3 Evidence from the Literature

Previous research has explored airline operations from both standalone and integrated perspectives. (Khanmirza et al., 2020) included passenger preferences and the capture of demand. (Birolini, Jacquillat, et al., 2021) looked at how supply and demand interact. (Ding et al., 2023) combined airline operations decisions with crew costs using game theory. More recent studies are paying attention to sustainability, such as hydrogen infrastructure and carbon policies (J. Wu et al., 2025) and fuel-cost optimisation in Brazil (Eskenazi et al., 2026)

Airline operations research has also grown into technology-based approaches. (Ben Ahmed et al., 2022) created a framework that links several airline operations planning decisions. (Moreno et al., 2023) focused on tail assignment. (Pereira Barreto et al., 2021) added fault prediction. Learning-based methods are becoming more important; (Thakkar & Palaniappan, 2024) mix programming with reinforcement learning and (Birolini & Jacquillat, 2023) use data to predict delays. Robustness has also been examined by (He et al., 2023) and by the SUP-RAR tool from (Akıncılar & Güner, 2025)

Among all the approaches crew-related optimisation is the most advanced research stream. (Zeighami et al., 2020) used decomposition while (Feng et al., 2023; Huang et al., 2022; Neufeld et al., 2021; Wang et al., 2022) used branch-and-price and column generation. Machine learning has also been used for neural-network clustering and connection prediction, by (Yaakoubi et al., 2020) followed by the CNN-based optimiser of (Tan & Xu, 2023). Recent research looks more at crew wellbeing with (Benson, 2020; Qin et al., 2020) and (Ong et al., 2026) adding fatigue and weariness to airline operations scheduling decisions.

3.4 Primary Studies Across Three Scheduling Stages:

	Study	Year	Stage	Method/Contribution
1	(Zeighami et al., 2020)	2020	Crew scheduling	Lagrangian decomposition linking crew pairing and rostering.
2	(Khanmirza et al., 2020)	2020	Fleet assignment	Heuristic for integrated schedule design and fleet assignment with demand recapture.
3	(Yaakoubi et al., 2020)	2020	Crew scheduling	To build initial clusters for a traditional crew-pairing OR optimiser, flight-connection prediction is used.
4	(Birolini, Antunes, et al., 2021)	2021	Fleet assignment	enhanced supply-demand interaction modelling combined with fleet assignment and flight scheduling.

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5	(Ben Ahmed et al., 2022)	2022	Fleet + routing + crew	Matheuristic for the fully robust integrated fleet assignment, aircraft routing and crew pairing problem.
6	(Ding et al., 2023)	2023	Fleet assignment + crew	The impact of crew hotel costs on fleet assignment and crew matching is examined using game theory.
7	(Birolini & Jacquillat, 2023)	2023	Aircraft routing	Day-ahead aircraft routing using data-driven primary-delay predictions.
8	(He et al., 2023)	2023	Aircraft routing	Maximises routing robustness against heterogeneous maintenance-task requirements.
9	(Tan & Xu, 2023)	2023	Crew scheduling	Convolutional-neural-network-based optimisation algorithm for airline crew scheduling.
10	(Thakkar & Palaniappan, 2024)	2024	Aircraft routing	Reinforcement learning and dynamic programming are used for customer-focused routing.
11	(Nourmohammadzadeh & Voß, 2024)	2024	Fleet + Crew	Matheuristic approach to robust airline fleet and crew scheduling.
12	(Akıncılar & Güner, 2025)	2025	Aircraft routing	SUP-RAR: a dedicated tool for robust aircraft routing.
13	(Gullbekk et al., 2025)	2025	Crew Scheduling	Solves the crew scheduling problem specifically for long-haul airline operations.
14	(Eskenazi et al., 2026)	2026	Fleet assignment	Fuel-optimal fleet assignment applied to the Brazilian domestic

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				air transportation system.

3.5 Strengths and Weaknesses of Previous Research

Across all three phases, the most visible trend has been the evolution from simple deterministic models to integrated robust models. Crew expense and schedule development are currently frequently affected by Fleet (Ding et al., 2023), data-driven delay prediction (Birolini & Jacquillat, 2023) and reinforcement learning (Thakkar and Palaniappan, 2024) are increasingly being incorporated into routing. The first discipline to arrive was crew scheduling , with machine-learning articles dating back to 2020 (Yaakoubi et al., 2020). It is also encouraging that there is now a comprehensive reference book that covers all three phases (Wandelt et al., 2026). This indicates that the area has developed enough to be taught rather than only published in bits and parts.

However, the weaknesses are not uniformly distributed. The majority of 'integrated' claims in this literature are actually merely two phases merged because fully integrated three-stage models are still uncommon. The sole publication that covers all three at once is (Ben Ahmed et al., 2022). Only(Akıncılar & Güner, 2025) really address aircraft routing, which is the smallest stream and has very little robustness research. Additionally, although crew scheduling has the greatest number of publications, its optimisation study and human-factors research remain mostly distinct (Benson, 2020; Ye et al., 2025)

3.6 RESEARCH OBJECTIVE

Our research objectives for this study are:

1. Determine the frequency with which fleet assignment, routing, and crew scheduling are solved as a single integrated problem rather than one after the other.

2. Determine whether or not machine learning is becoming more prevalent in crew scheduling compared to fleet assignment or routing.

3. Check whether robustness strategies developed for one stage (crew scheduling, so far) are truly being applied to the other two, or if each stage is redefining robustness independently.

4. DATA ANALYSIS AND RESULTS

4.1 Publication Trends

The bibliometric dataset for this review was built by employing the five-stage PRISMA screening procedure ending with a final unique corpus of 521 articles generated from the combined Google Scholar/Mendeley and ScienceDirect searches on "Airline Scheduling" (2020-2026). From these, 500 entries had full year-of-publication metadata and were used in the Annual Scientific Production study in Biblioshiny.

As illustrated in Figure 1, annual output was very low (40 articles) in 2020, increased to 49 articles in 2021 and 50 articles in 2022. This was essentially a two year plateau before rapidly increasing to 62 articles in 2023, 78 in 2024, 95 in 2025 and 124 at the time of data extraction in 2026. This last figure should be taken with a grain of salt, as data was only collected through August 2026, so the 2026 count represents only a partial year of indexing,

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and already exceeds the figure for the entire year 2025. This indicates continued acceleration, rather than a true outlier.

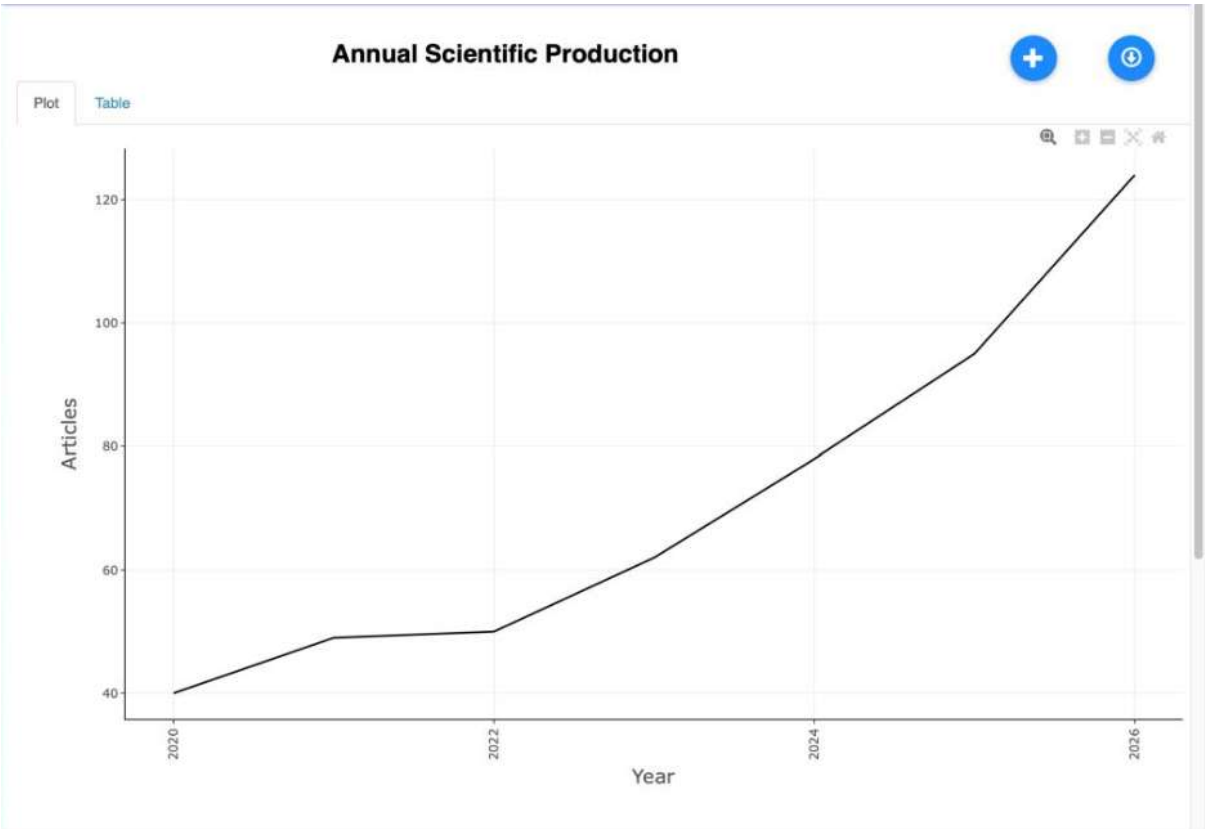

Figure 1. Annual Scientific Production of Airline Scheduling research, 2020-2026

The year wise counts were fitted with an exponential trend line (y = 38.10e0.184x, R2 = 0.973) which revealed an approximate 20% annual growth rate, and confirmed that the publication growth in this domain is consistent with the traditional exponential pattern of an actively increasing research domain. This is similar to the 37.98% year-on-year growth for on-demand video-streaming research (y = 1.6918e^0.3337x, R = 0.9158, 2011–2022) by Saxena (2023). Airline scheduling has been an operations-research problem for a long time, rather than a newly-emerging consumer-technology topic. One would expect it to grow steadily rather than rapidly. The rapid acceleration from 2023 onwards coincides with the industry's post-pandemic recovery and a renewed focus on schedule resilience, disruption management and recovery optimisation. The almost flat period between 2021 and 2022 probably reflects the residual disruption that COVID-19 caused to both airline operations and the research pipeline feeding this literature.

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Thematic Mapping

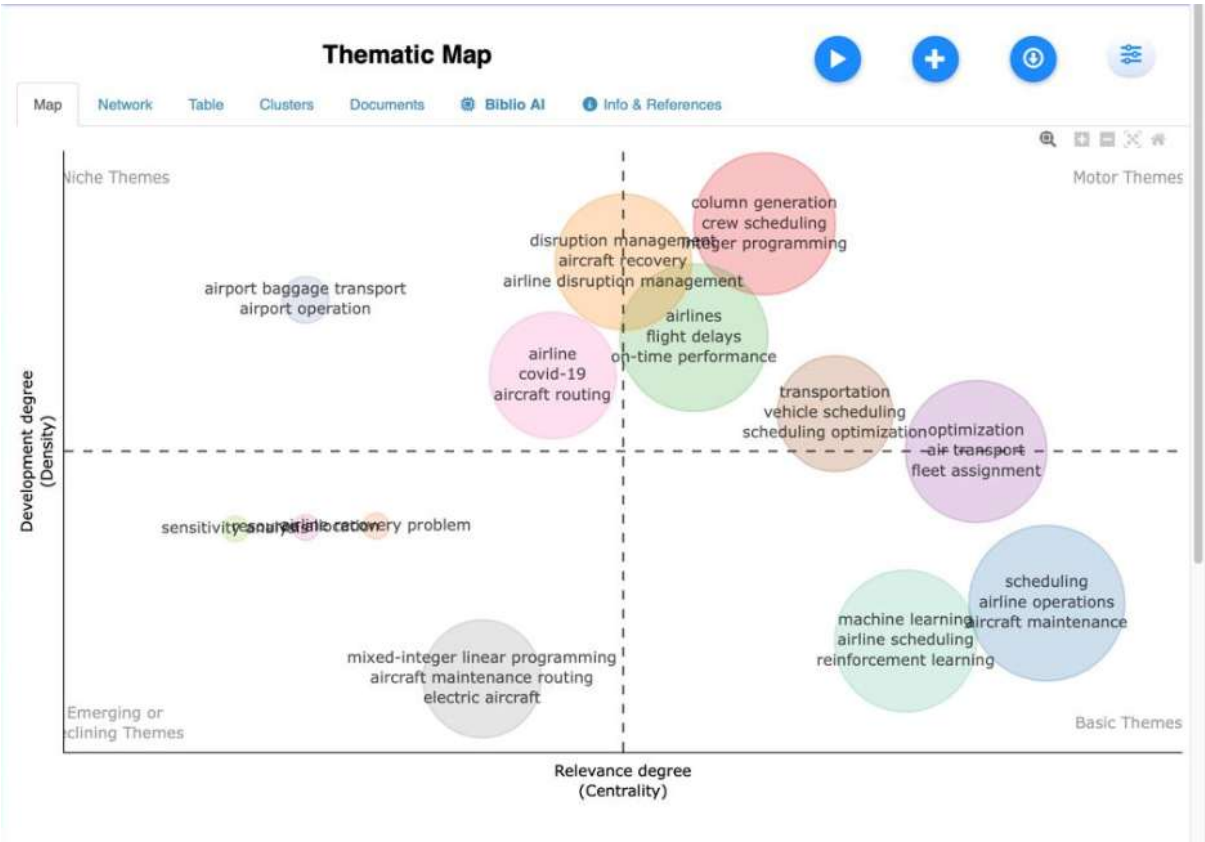

Figure 2. Thematic map of keyword clusters by centrality (relevance) and density (development)

Figure 2 is a thematic map of a field with a high degree of motor core development and a relatively thin basic/foundational layer, built on the basis of keyword co-occurrence and split into four quadrants by centrality (relevance, x-axis) and density (development, y-axis).

The upper right quadrant is dominated by motor themes (high centrality, high density). Column generation, crew scheduling and integer programming form the strongest most internal cohesive cluster, with a close overlap with disruption management, aircraft recovery, flight delays and on-time performance. Together, these three groups of overlapping papers suggest that the sophisticated, highly interwoven core of the modern airline scheduling research field comprises exact and heuristic optimisation methods, specifically column generation and integer programming, and their application to crew scheduling and disruption/delay recovery.

On the left-hand side of the image, niche themes (high density, low centrality) are represented as two smaller, more autonomous clusters: airline COVID-19/airplane route and airport baggage transport/airport operation. These are well-developed but relatively isolated sub-topics, the latter perhaps indicating a COVID-19 pandemic surge in routing research that has not yet been fully absorbed into the wider thematic fabric of the field.

Transportation, vehicle scheduling, schedule optimisation, air transport, fleet assignment and other basic themes are close to the vertical division, slightly below the horizontal midline. These are more a traditional trademark of fundamental vocabulary that most airline-scheduling studies reference or build upon, rather than a specialist theme in and of themselves. They are broadly applicable structures that span across many other clusters without establishing a tightly-knit research program of their own.

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In the lower half of the map, which contains the emerging/declining and basic quadrants, there are a number of interesting clusters. A small, tightly packed cluster sensitivity analysis / airline recovery problem very near the edge of the origin suggests a low strength theme that is still developing. In the lower middle of the map, we find a larger cluster, mixed-integer linear programming/aircraft maintenance routing/electric aircraft. The rise of "electric aircraft" here is particularly interesting as it suggests that maintenance-routing research including next-generation or electric aircraft, while still low in centrality, is an emerging strand that is worth tracking in future data extractions as sustainable-aviation considerations gain traction. In the lower right quadrant, two large, basic-to-motor-adjacent clusters optimisation / air transport / fleet assignment and scheduling / airline operations / aircraft maintenance overlap with machine learning / airline scheduling / reinforcement learning, suggesting that data-driven and learning-based approaches to airline operations and maintenance scheduling are gaining a real, but not yet fully central, foothold in the literature.

Overall, the map indicates that classical and disruption-aware optimisation techniques are the current focus of airline scheduling research, while approaches based on machine learning/reinforcement learning and sustainability-related topics such as the maintenance routing of electric aircraft are promising but still-developing directions that future studies in this field, including the current group's research agenda, could profitably expand upon.

5. FUTURE RESEARCH AGENDA

5.1 Findings and Research Gaps

There is literature-based evidence that it will be possible to use a wide variety of methods in airline and airport operations research but that there is a lack of uniformity and integration. There has been many studies on the subject of recovery (Abdelghany & Abdelghany, 2026; Chen et al., 2026; Miao et al., 2026; Wandelt, Wang, et al., 2025) and (Du et al., 2026) integrate air-rail capacity, deep reinforcement learning, schedule recovery and gate reassignment. However, most models still focus on the resources of flight, fleet, crew, cargo and traffic management separately (Zhou et al., 2025). The same is true for dealing with uncertainty. In fleet management, tail routing and maintenance (TRM) (Ben Ahmed et al., 2022; Glomb et al., 2024; Weide et al., 2022), chance constraints are becoming more common, but are usually added as an additional constraint on the deterministic base, which is incompatible with it making cross-study comparison impossible.

The difference is also apparent when it comes to predictive AI. The field of feature engineering is one area where machine learning has been used, as well as solution-space reduction (Rashedi et al., 2025) and delay-probability forecasting (Beltman et al., 2025). These informative reviews, however, show that a larger number of components are suggested as predictors than are found to have a positive effect on optimisation in empirical studies. (Ouhadi et al., 2024; Razzaghi et al., 2024; Wandelt, Signori, et al., 2025). Similarly, factors of fatigue, preferences, quality of life and retention (Bartulović & Grgić, 2025; Hickey et al., 2026; Venus & grosse Holtforth, 2022) are explored independently of cost models, and emissions are increasingly becoming a planning objective (Barry & Stuart, 2026; Miao et al., 2026) rather than a secondary constraint. It should also be noted that the availability of data is still a key challenge in digital-twin research (Du et al., 2026). As a whole, these findings highlight the four weaknesses in structure that were identified in this agenda: separated recovery decisions, pasted-on uncertainty, isolated human factors and unbenchmarked innovation.

5.2 IMPLICATIONS

The programme is useful for those working in the area of airline and airport operations research, to give an idea of which problems are worth investigating jointly and where there is little evidence. The head-to-head comparison of the sequential and jointly optimised recovery model with the common measures of schedule stability and the tuned classical OR baselines would enable scholars to compare methods in a consistent manner,

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which is currently challenging. These findings assist scholars in deciding which areas of research to pursue that fit in with the times and gaps in knowledge. There are some areas where novel contributions can be made, such as emissions as a core planning objective, human centred schedules, extension of recovery principles to air-rail and urban air mobility networks.

Specifically, from an industry perspective, the agenda could be used to identify under-explored areas in research and to assess the viability of introducing the ideas within their organisations. Coordinating airline decisions with network-manager constraints (Wu et al., 2026), and testing sustainable formulations in realistic carbon pricing and fuel alternatives demonstrates the relevance of developing planning systems which are resilient and robust to disruption and regulation. The open datasets and shared simulation infrastructure proposed here could also be used to benchmark practitioners' own decision support tools.

In short, the results have value to any researcher interested in creating an article on a topic as well researched as airline planning, and as a proof that not everything in the topic has been studied and gaps exist which can be investigated further. Research activities and priority actions highlighted in this agenda could be used as a point of reference by the industry to look at what they do and determine strategies and best practices

6. CONCLUSION AND LIMITATIONS

To conclude this study looked at how research on airline scheduling has grown over time using an analysis of the literature. The goal was to find out what research trends are emerging, to understand the topics and connections shown in keyword analysis and to build a future research plan based on gaps and new directions found in the studies.

The results show that airline scheduling is a growing area of research. The number of publications went up from 40 records in 2020 to 124 records in 2026. The analysis revealed methods and operational ideas pointing to the key areas of focus within the field. Thematic analysis also shows that airline scheduling research is slowly shifting away from optimizing resources. It is now moving toward complete decision-support systems that include uncertainty, human behavior, sustainability and new technologies. These changes offer paths forward for both researchers and people working in the airline industry.

However, there are some limits to keep in mind when looking at these results. First the study used 500 publications so it might not cover all the research done on airline scheduling. Second the search method could have missed studies that use words or ideas to talk about airline scheduling problems. Third the data covers the years 2020 to 2026, which gives a recent view but not a full history of the field. Also the number of publications listed for 2026 should be seen carefully because that year is still ongoing.

Finally, another big challenge in this research area is getting access to real-world data. Information like flight schedules, operating costs and airport financial details is often not open to the public. Getting this data usually requires requests. This lack of data can make it hard to test models. Applying them in practice remains an issue that needs more attention in future work. With these limitations the study gives a clear picture of current research in airline scheduling and points to new directions that can help move the field forward.

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