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Investigation of Breaking Points in the Airline Industry with Airline Optimization Studies Through Text Mining before the COVID-19 Pandemic

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Abstract

In this study, current literature in the field of airline optimization has been examined by the text mining method to understand trends and commercial threats in the airline industry. Prominent types of work and popular topics have been revealed to understand the importance of global events. This research summarizes trends and some important points relating to airline optimization. The results are striking. It analyzes studies conducted on behalf of aviation before the global COVID-19 pandemic. The economic contribution made by the aviation sector as well as the costs it suffers as a result of crisis situations are clearly explained. Reasons for differences in studies conducted by different countries in the field of aviation are also explained. This study is intended to give an idea of how the aviation sector shapes academic studies, how studies on aviation optimization could contribute in the future, and how the countries have addressed important challenges to the aviation industry in the past.

In the modern era, the issues of moving and transportation have presented many problems and have thus been popular areas of study. In aviation, as in every field of business, it is important to follow and monitor dynamic trends and the changing business environment. Air transportation has grown in popularity and become the primary way of transferring passengers and perishable products over long distances. The aviation industry has faced many crises in its history, such as the oil crisis and the September 11 crisis. Changing conditions created by such crises force states and other relevant organizations to react and, in some cases, impose travel ban or limits on what can be carried in aircraft. As a sector that is integrated with many others, the aviation industry is often most affected by sanctions and difficult international situations. The COVID-19 pandemic is no exception; it has disrupted the aviation industry across the world. To address the current crisis, it may be helpful to examine how the aviation sector has coped with previous crises, using analysis of published sources. In this context, optimization studies looking at how the airline industry has coped under changing and developing environmental conditions have become an important tool.

The International Air Transport Association (IATA) annual review for 2019 reported that the industry had carried 4.1 billion passengers worldwide (*1*). In addition, global airline revenues amounted to US$865 billion, a record for the industry (*2*). The increase in passenger numbers creates the need for continuous efforts to meet demand and increase capacity. The literature reveals many issues and problems in the field of airline optimization. Although all of these studies and their conclusions can provide useful information, recent studies have shown that, despite their best efforts, optimization studies that have been carried out around the world have not made a significant contribution to income, as shown in Figure 1.

Nonetheless, such studies have undoubtedly made an important contribution to the field of air transport and management and have shed light on possible future work. It is, therefore, necessary to explore new trends

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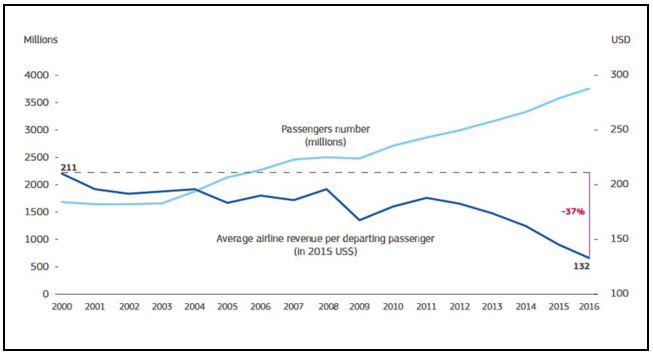

Figure 1. Worldwide passengers and average airline revenue per passenger.

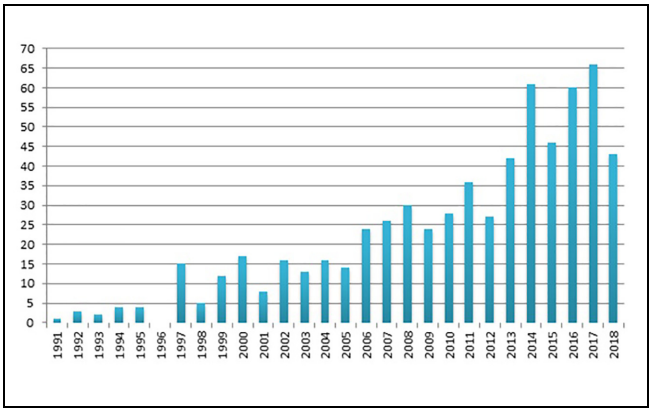

Figure 2. Published studies per year.
Source: Thomson Reuters—ISI web of science, 2018.

that might yield better results and contribute to development and revenue growth. This study aims to determine the breaking points and emerging trends highlighted in previous studies in addition to occasions that have created difficult predicaments for the industry. We have examined more than 700 studies published between 1991 and 2019, using the keywords "airline" and "optimization."Figure 2 shows the number of publications each year. The framework of the study is constructed as follows: in the following section, text mining approaches to aviation and airline optimization are examined. We then describe the details of the text mining study, which is carried out with the keywords "airline" and "optimization." The next section describes the findings of the experimental study, analysis of variance (ANOVA) statistics, as well as a visualization of the results obtained. Finally, the results of the study are discussed, and conclusions made.

Literature

The literature search was performed by scanning studies conducted between 1975 and 2018 using the Thomson Reuters—ISI Web of Science database. As can be seen from Figure 2, there was a noticeable increase in the number of studies after 2000. Among the total of 781 studies in the field of airline optimization up to the end of 2018, the highest number was carried out by the United States with 229 studies and by the People's Republic of China with 118 studies, as shown in Table 1.

Table 1. Country Rankings on Number of Publications until the End of the Year 2018

Country	Number of publication	Percentage of total publication (% of 781)
USA	229	29.32
China	118	15.11
B**	63	8.07
A*	55	7.04
Germany	44	5.63
Taiwan	37	4.74
Turkey	31	3.97
Canada	30	3.84
France	24	3.07
UK	22	2.82
India	19	2.43
Japan	16	2.05
Australia	15	1.92
Italia	13	1.66
Netherlands	12	1.54
South Korea	11	1.41
Spain	11	1.41
Sweden	11	1.41
Qatar	10	1.28
Singapore	10	1.28

*Countries that have less than five publications.
**Countries that have between four and 10 publications.

Knowledge discovery and data mining in databases have recently attracted the attention of a significant number of researchers and industry professionals (*3*). The vast majority of this interest has been inspired by the urgent need for new methods and better information. Data analysis methods using known procedures are based on conventional processes; at the same time, manual analysis can produce only person-specific interpretations.

Conventional data analysis can be time-consuming, expensive, and highly subjective. This is why knowledge discovery and data mining techniques are needed. Text mining, a method of data discovery, is a new tool that will help to eliminate failures, save time, and provide more precise information. Text mining involves the use of automated methods for exploiting an enormous amount of knowledge available in text documents (*4*).

Although text mining techniques vary widely, it is known that the method provides useful information in areas where it is applied (*5*). Business intelligence, bioinformatics, pharmaceuticals, and Energy are areas where text mining techniques have been used. Kim et al. (*6*)

performed a study into bioinformatics that aimed to generate a system to provide reference materials to let NLP techniques work in bio-text mining. Also, they used text mining techniques to identify trend topics and study clusters in the area of wind energy (*7*). Shi et al. (*8*) used a methodology perspective to identify risk factors in safety management systems. Irwin et al. (*9*) introduced a visual data exploration technique for compiling, reducing, organizing, visually rendering, and filtering text-based narratives for detailed analysis.

In addition, many studies have been conducted on airline crisis management and analysis. Some of these studies have evaluated crisis management philosophy, while others have tried to explain crisis structures statistically. While crisis management studies have been conducted into airline companies (*10*), there are also studies examining the measures and positions taken by airline companies within the framework of current crisis situations (*11*). The work carried out has been evaluated and analyzed not only on crisis management but also within the scope of public relations (*12*). Although there have been many studies on this issue in recent years emphasizing crisis management and leadership, few of them have been described as ethical. A good example of such a study was carried out by Varma arguing that actions taken during a crisis within the responsibility compass affect reputation (*13*). Based on this, in this study, crisis situations and the effects of the measures taken, along with working trends, were investigated.

Although the airline applications of text mining studies are not yet widely used, it is possible to find some applications in areas of text mining techniques. Most of these studies were carried out to determine customer behavior, information on which is used to develop services. Liau and Tan (*14*) conducted a survey, "Gaining Customer Knowledge in Low-Cost Airlines Through Text Mining," about the behavior of airline customers by using text mining. This study is an example of text-mining being used effectively by low-cost airlines to ascertain information about their customers and improve services.

Thus, this study could serve as a model for future feasibility studies in airline optimization and help identify emerging trends in the field.

Methodology

The primary mission of text mining in this study, which is carried out on airline optimization studies, is to identify tendencies in studies that have been done so far and to define what needs to be done in the future. The main steps of text mining are data gathering, data preprocessing, indexing, mining, and analysis.

Comprehensive searches using "airline optimization" are done to find as much relevant research as possible. The Thomson Reuters—ISI Web of Science database, used by researchers around the world, has been selected for use in this study. Only published articles and conference proceedings were reviewed, and the study area was narrowed to reveal specific features. Topics to be used in text mining were selected, anything irrelevant was screened, multinational publications published in multiple countries were singled out, and a dataset was created and stored in an excel spreadsheet while the data were prepared. The dataset was indexed and scanned using the text mining algorithm. ANOVA inferences, which are required for the analysis, were also implemented with the same software via the statistics extension.

Data Gathering

The abstracts of all available publications between 1991 and 2018 were obtained from the database and transferred to the excel spreadsheet. The database was constructed with the following categories: publication type, publication year, publication title, authors' name, authors' country, abstract, language, and source. Irrelevant editorial notes, research notes, patents, news, and reviews were not included.

While the publications were classified on a country basis, those countries with less than five publications were grouped as A, and those with between five and 10 were classified as group B. Data collected through this process were suitable for the text mining study.

Text Mining

Text mining is a set of operations using a text document as a data source that aims to obtain valuable structural information. This process requires complex analytical tools that process text to collect the required keywords as well as overlooked or crucial unprocessed data points. The process of text mining involved the following steps:

- The database was created as an excel spreadsheet and aligned with the relevant software.
- The abstracts from the publications were selected as a variable for the study.
- The indexing language was set as English, the maximum number of words to be chosen from documents was determined to be 3000, and the minimum frequency of the occurrence of words in a single document to be selected was 3%.
- Stop words, synonyms, and phrases were defined so that the text mining study could proceed.

The stop word list contains words that will not be included in the analysis (e.g., am, is, are, etc.). The

synonyms list contains words that should not be evaluated separately (study, studies, prefer, preferences, etc.). The phrase list contains words that should be evaluated as a single word. In addition to these, other words frequently used in academic literature such as "airline," "articles," "flight," "copyright," "Airbus," "Boeing," and so forth, were added to the stop word list. If there was more than one word with the same meaning (e.g., tendency, inclination, trend), it became synonymous with the previous word by merging operations. Default settings for word processing and filtering parameters for the text mining were used in the study.

- The processes described above enable the indexing process to start. There are many popular text retrieval indexing techniques similar to reverse indexes, and signature files exist. The index method indexes the variables defined in the database.

Following the indexing process, the concept extraction process is started by using these documents, and the possible concepts are monitored. There are four conventional methods for concept extraction. These are:

A. Raw statistics: raw statistics are extracted from the number of words in all documents.
B. Binary frequency: if there is a word in a document, the frequency is 1, else 0.
C. Logarithmic frequency: various transformations of frequency counts can be realized and derived. The frequency of use of words or terms usually indicates how dominant or essential a word is in a document. In particular, words that appear as high priority in the frequency count define the content of this document better. So, logarithmic frequency computes the frequency of a word in an indexed database by using the formula given in Equation 1.

$$F = 1 + log(wrf) \ where \ wrf > 0 \tag{1}$$

wrf is word raw frequency. Somehow, the frequency of the use of words does not indicate the importance of the article. For example, suppose a word is used so frequently in a study that is is deemed essential. If this word is used five times in article X and three times in article Y, it is not reasonable to say that article X is more important than article Y. For this reason, using logarithmic frequency is more suitable for this circumstance.

D. Inverse document frequency: this frequency is the relative frequency of different words. Another important index that can be used in further analyses is the relative document frequencies (df) of different words. For example, a term such as "airport" may frequently occur in all documents, while another term such as "destination" may only occur in a few. A common and very suitable transformation that shows both the uniqueness of words (document frequencies) and, at the same time, the overall frequencies of their occurrences (word frequencies) is called inverse document frequency (for the *i*th word and *j*th document) as in Equation 2:

$$idf(i,j) = \begin{cases} 0, & if \ wf_i = 0 \\ log\left(1 + \frac{N}{df_i}\right), & if \ wf_i \geq 1 \end{cases} \tag{2}$$

where

N: total number of documents,

wf_i: word frequency of ith word for whole documents, and

df_i: word frequency of ith word for the current document.

Inverse document frequency, which is considered the most effective tool for the reasons mentioned in this study, was used. In light of this method, concept extractions are made. In our study, there are 17 concepts. Clustering techniques were applied to define clusters of similar documents, and the ANOVA test was used to analyze the differences between the related procedures.

Experimental Results

In this section, the data obtained from the studies and the inferences about the sector were interpreted, and a vital direction was determined for future studies. The direction determined in this context has an important place in the process of change in the last years.

Based on more than 700 articles, the total number of words selected was 847, and a list of the top 30 essential words is given in Table 2. This table shows that the problems related to "crew," "delay," "airport," "recover," and "rm (revenue management)" are the top five most essential topics throughout "airline optimization" studies.

Scores and rankings of the concepts obtained following the processes of indexing and conceptualization are shown in Table 3, and the most essential words for each concept are given in Table 4. As a result of the studies outlined in Table 4, the meanings of the concepts are shown in Table 5.

If Tables 2 and 4 are examined comparatively, it can be seen that the most essential words presented in the study are not the same as the most essential words revealed by the concepts. In this context, it can be said

Table 2. Top 30 Important Words

	Word	Importance (%)		Word	Importance (%)		Word	Importance (%)
1	crew	100,0000	11	price	75,5059	21	route	65,7078
2	delay	96,0511	12	air	74,4932	22	control	64,1205
3	airport	88,2475	13	disruption	71,1275	23	class	62,9220
4	recover	84,9676	14	fuel	70,6744	24	flight	62,5585
5	rm	84,5816	15	demand	70,4847	25	capacity	61,8825
6	maintain	83,6545	16	network	69,7114	26	gate	61,5256
7	revenue	80,7873	17	traffic	69,5901	27	schedule	61,4209
8	fleet	77,2015	18	system	68,0795	28	fare	61,2733
9	emission	76,2308	19	transport	66,7045	29	operation	60,8052
10	aircraft	76,0468	20	pair	66,4224	30	policy	60,6088

Table 3. Concept Scores and Rankings

Rank	Concept	Score	Rank	Concept	Score
1	Concept 1	157,345	10	Concept 10	48,454
2	Concept 2	72,894	11	Concept 11	47,901
3	Concept 3	66,085	12	Concept 12	46,980
4	Concept 4	60,402	13	Concept 13	46,272
5	Concept 5	55,992	14	Concept 14	45,817
6	Concept 6	54,141	15	Concept 15	45,130
7	Concept 7	52,446	16	Concept 16	44,013
8	Concept 8	51,664	17	Concept 17	43,468
9	Concept 9	50,362			

Table 4. The Most Important Words of Extracted Concepts

	1. Rank	2. Rank	3. Rank	4. Rank	5. Rank	6. Rank	7. Rank
Concept 1	aircraft	flight	delay	operation	network	schedule	system
Concept 2	revenue	price	rm	fare	demand	customer	control
Concept 3	revenue	policy	fare	booking	class	seat	overbooking
Concept 4	rm	bus	items	factor	mode	business	node
Concept 5	crew	side	user	period	would	pairing	now
Concept 6	workload	pilot	rm	ground	delay	weather	disruption
Concept 7	fleet	pilot	design	market	decision	aviation	process
Concept 8	recover	disruption	maintain	support	center	control	application
Concept 9	air	multi-objective	application	airport	network	system	design
Concept 10	disruption	robust	market	itinerary	network	choice	price
Concept 11	gate	total	fly	airport	security	rate	station
Concept 12	emission	speed	price	co_2	consumption	carbon	burn
Concept 13	cargo	hold	industrial	rm	authors	airport	congestion
Concept 14	itinerary	statistics	data	travel	carrier	pair	historical
Concept 15	dual	lp	program	integer	optimal	partitioning	rm
Concept 16	exist	cargo	capacity	co_2	load	hub	overbooking
Concept 17	rm	departure	forecast	trajectory	step	support	capacity

that concepts are a more useful approach than simply seeking to make sense of the words obtained more generally.

The text mining study produced more than 800 words under a total of 17 concepts. Concepts and words are clustered and listed. It was seen that the words contained in the concepts were not the same as the words set out in the totals and which were examined and interpreted. It was seen that the concepts listed notably included fewer and more meaningful words, and the number of words increased in the concepts that were considered insignificant. To reach more accurate information and to provide

Table 5. Concepts and Focus Areas

Concepts	Focus area
Concept 1	Aircraft Operation Network Scheduling
Concept 2	Revenue and Price Management
Concept 3	Revenue and Booking Fare Policy
Concept 4	Effects of Business Factors on Revenue Management
Concept 5	Crew Pairing in a Period
Concept 6	Workloads of Pilots on Revenue Management
Concept 7	Fleet Assignment and Pilot Decision
Concept 8	Maintaining and Recovering Operations
Concept 9	Multi-Objective Airline and Airport Network Operations
Concept 10	Robust Market İtinerary Choice
Concept 11	Airport Gate Assignment
Concept 12	Green Fleet Design
Concept 13	Cargo Airport Congestion İmplications
Concept 14	Itinerary Statistics Data and Travel Carrier Pairing
Concept 15	Revenue Management on Dual LP Program
Concept 16	Cargo Capacity Management on Hubs
Concept 17	Revenue Forecasting on Departure Trajectory

a more detailed examination, ANOVA analysis is used. The internal dynamics of the study with ANOVA analysis were investigated, and internal and external factors were investigated and analyzed. When performing ANOVA analysis, the confidence interval was 95%. Data that do not meet this confidence interval are considered meaningless and are excluded from the study. It can be seen that only Concepts 1, 5, and 12 have developed meaningful relations over the years if the publication year and concept relations are examined under these conditions. The confidence interval of the other concepts was found to be insignificant as it did not meet the 95% criteria and was not examined in this context.

It can be seen from Figure 3 that Concept 1 has had a tendency to fluctuate over the years. It can be said that there was a significant fluctuation especially between the years 1991 and 2000; after 2000 it became stationary and vital. The majority of the studies carried out under this concept can be seen to have been conducted by Qatar. It is undeniable that Concept 1 is essential for the development and globalization of an airline. Besides Qatar, work on "Aircraft Operation Network Scheduling" was conducted in India, UK, Italy, and Turkey.

The 73% growth in intercontinental traffic (*15*) has justified and triggered the airlines' need to grow, especially regional services in all parts of the world, to meet current and future passenger demand. On the other hand, the increase in global and regional passenger traffic has required airlines with global networks to revise their fleet to serve more passengers.

Considering Figure 4, it can be said that Concept 5 has had a stable trend over the years. However, in 1998, Concept 5 showed a dramatic increase, accelerating the work done in this area. When the causes of this rise are investigated, the apparent reasons for France's interest in this area can be elucidated and made concrete.

In the early 90s, in both Europe and Asia, Taiwan's status was controversial. As a result, Air France was unable to fly to the island under its own name. In 1993, the other subsidiary of Air France named Air Charter started to fly between Hong Kong and Paris. However, Air Charter ceased operations in 1998 and a new subsidiary, Air France Asie, was established (*16*). With the establishment of this new airline company, the increase in the number of destinations in France brought an increase in aircraft. At the same time, the increase in the number of airline passengers, both around Europe and on intercontinental routes, area required more cabin personnel and pilots. Since this requires significant costs, many airlines, particularly Air France, have investigated the issue of crew pairing.

Concept 12, which is considered a significant concept according to a 95% confidence interval, has had a significant and stable trend in recent years. The "Green Fleet Design" concept, which has grown steadily, has remained stable in the literature since emerging in 1991. It is now stable and suitable for development. Figure 5 clearly shows that the most prominent among the countries that have worked in this field are the UK, South Korea, and Spain. The most important reason for the dramatic increase in the green fleet design study area in 1992 was the Kyoto Protocol. The Kyoto Protocol was an agreement reached in 1997 to extend the 1992 United Nations Framework Convention on Climate Change (UNFCCC), under which states pledged to reduce greenhouse gas emissions, based on scientific consensus, to address global warming. Man-made CO_2 emissions are highly likely to cause greenhouse gas emissions. The Kyoto Protocol was adopted on 11 December 1997 in Kyoto, Japan, and was put into effect on 16 February 2005. But the impact of work to tackle climate change had begun to be felt since UNFCCC in 1992. Aviation accounts for approximately 2.1% of global CO_2 emissions—roughly equivalent to Germany's total emissions. International flights account for around 1.3% of global emissions (*17*).

Also, it is known that fuel burn from commercial aircraft increased by 71% between 1992 and 2006 (*18*). Overall, between 1990 and 2004, CO_2 emissions from the EU aviation sector rose by 73%. Six countries (UK, Germany, France, Spain, Italy, and the Netherlands) are responsible for 82% of the total emissions.

All of these studies and articles written shed light on the situation and provided us with the opportunity to acquire new information and inspired ideas for us to expand our focus. Furthermore, after examining the relationships between the concepts considered meaningful,

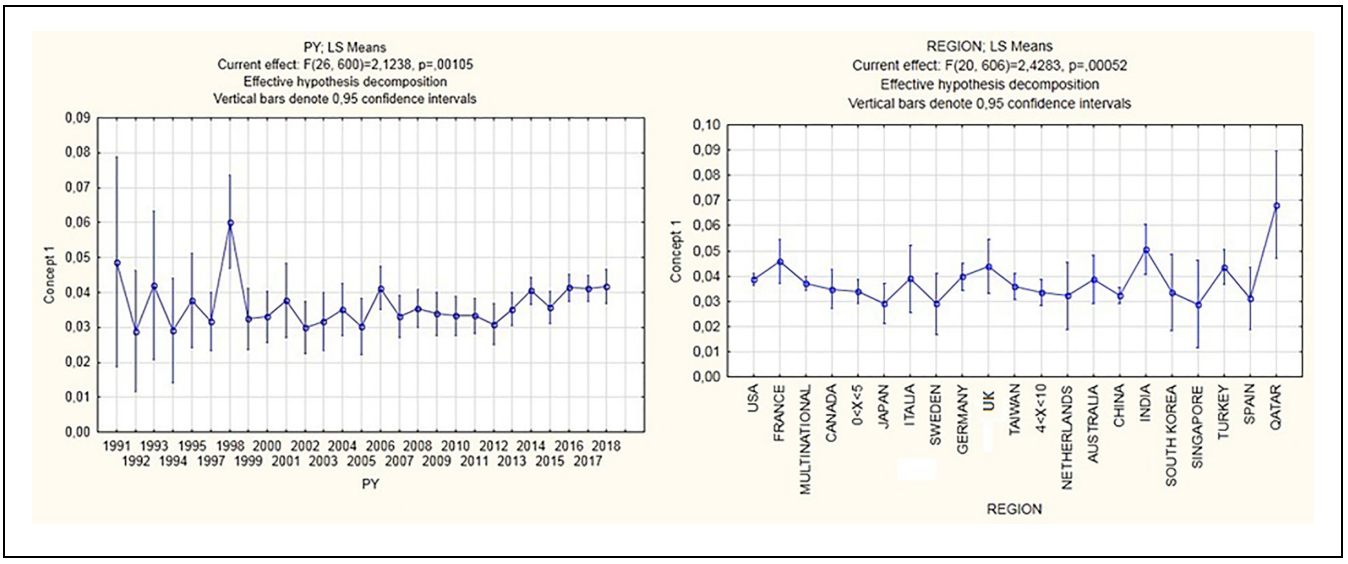

Figure 3. Analysis of variance for Concept 1 versus publication year/region.

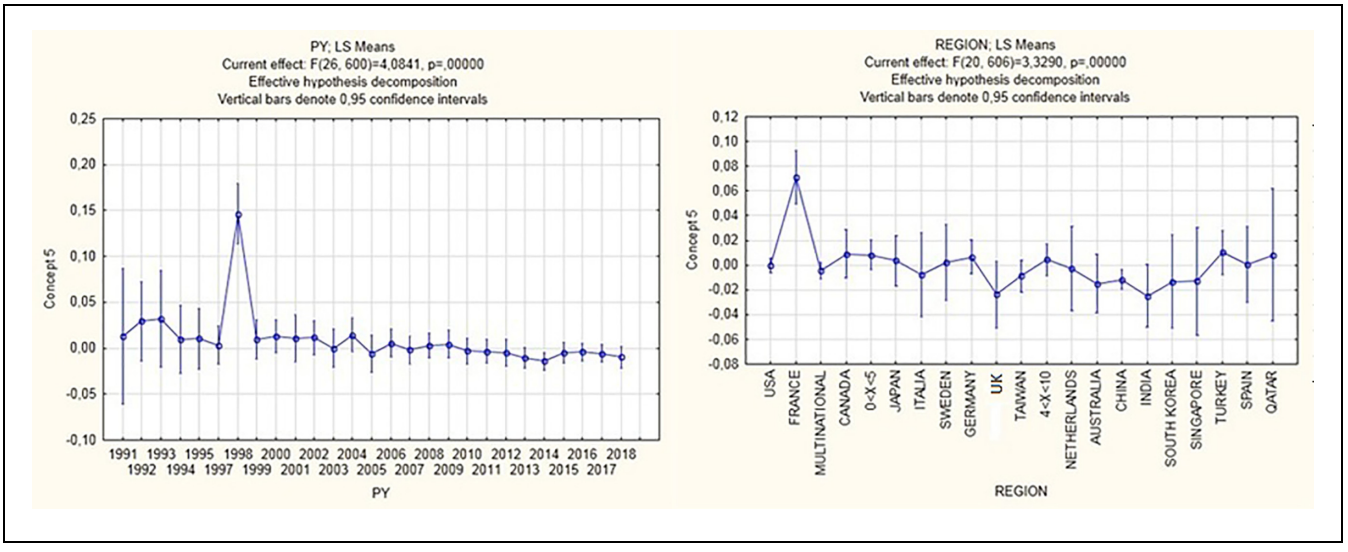

Figure 4. Analysis of variance for Concept 5 versus publication year/region.

some words and their relationships with matching countries led us to examine the confidence interval. The words studied are frequently used words that are strictly related to aviation studies. The scope of these words continues to evolve.

Figure 6 presents the studies related to "rm" (revenue management) and "short-term" across counties. Qatar, which is the prominent country in the analysis of both rm and short-term topics, worked in this field taking an appraoch noticeably different than other countries. One of the reasons why rm has been given so much weight in these studies is that Qatar is a small but high-income country. The need to manage large amounts of income is not a matter of concern in this sense. It is surprising that none of this revenue was created by the aviation sector, which has achieved great success for Qatar in a short space of time.

Because Qatar cares so much for its short-term prospects reflects the irregular and unsafe airspace in the Middle East. An example of a more pressing airspace dispute lies in Qatar, where an airspace blockade of the country by its Persian Gulf neighbors has continued since June 2017. This was imposed collectively by Bahrain, Egypt, Saudi Arabia, the UAE. It has an overnight impact on Qatar Airways affecting the company's financial standing. The insecure airspace idea brought about

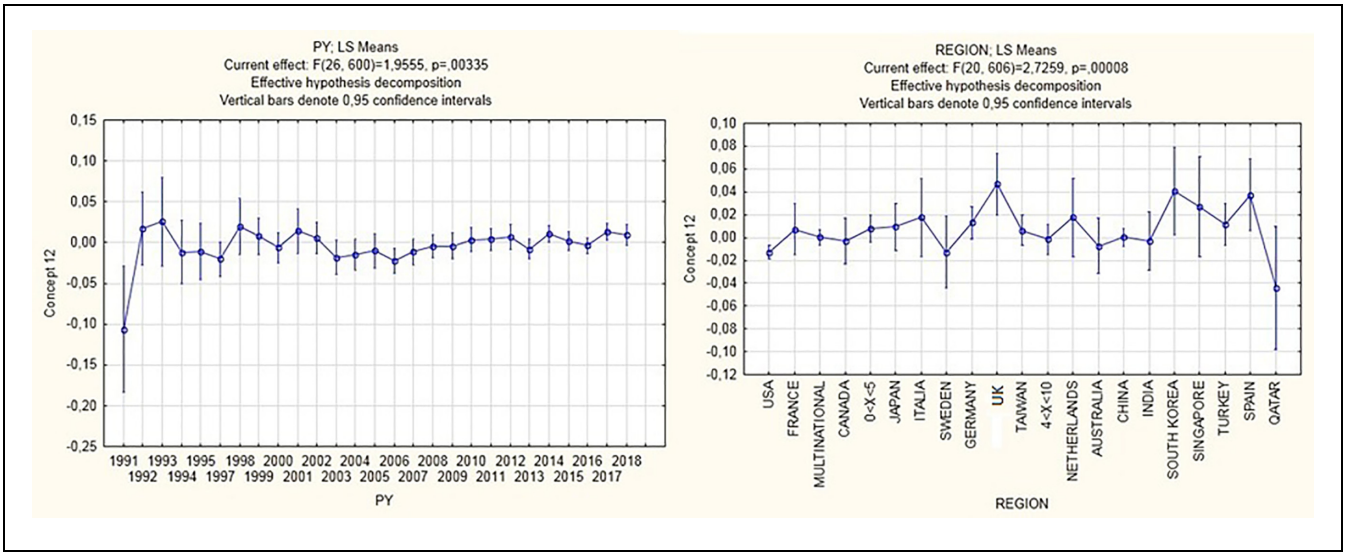

Figure 5. Analysis of variance for Concept 12 versus publication year/region.

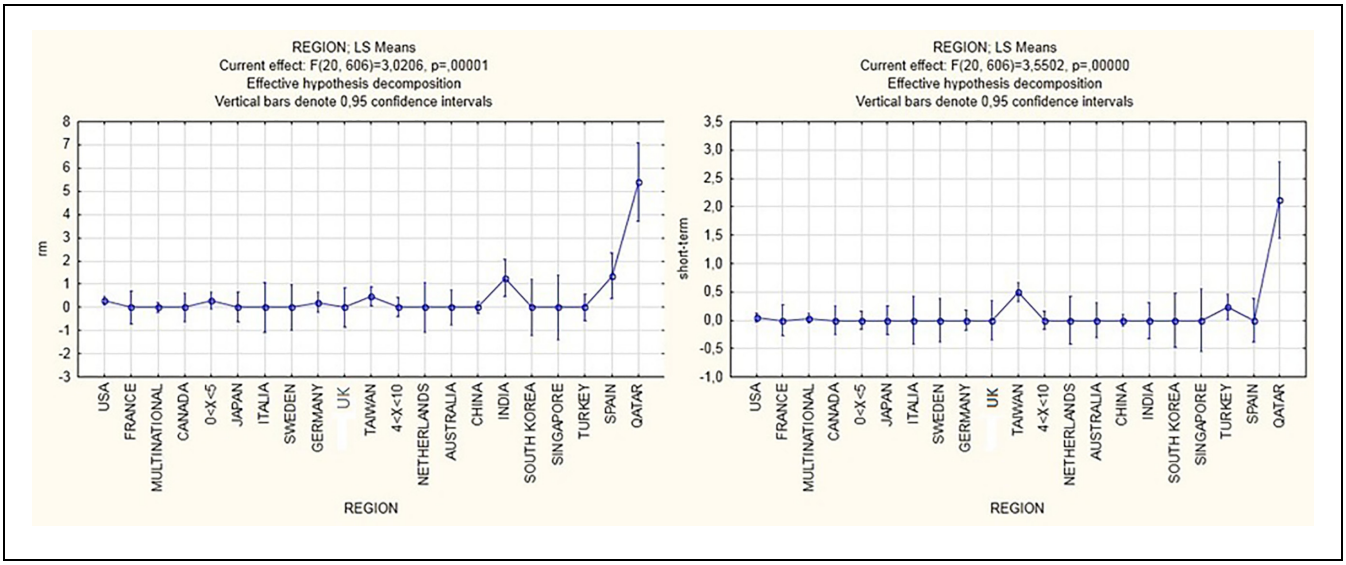

Figure 6. Analysis of variance for regions versus rm and short-term words.

by the continuous economic and political uncertainty in the Middle East led to the short-term arrangements put in place not only by Qatar but also all other airlines in the Gulf region, who set about arranging their flights to cope with the new situation. Although countries in the Gulf other than Qatar have large airline companies, it is seen that Qatar is the country that has directed the most effort toward studying short-term planning in the region.

As a result of their unstable airspace, Qatar Airways has launched a new road and flight network structuring process that could be vital for the operations involuntarily. To overcome these constraints, Qatar Airways organized its routes in the banned countries with 16 new destinations in 2018/19, including plans to become the first Gulf airline with direct services to Luxembourg. These initiatives explain why Qatar Airlines was prominent in routing studies, as shown in Figure 7.

On the other hand, one of the reasons why the UK attaches great importance to routing is the presence of one of the main hubs of Ryanair. Ryanair is an Irish low-cost airline founded in 1984 and has become one of the world's top passenger carriers. Its central hub is located at London Stansted Airport. Also, India is known to be one of the largest civil aviation markets in the world. Airlines operating in India connect more than 80 cities

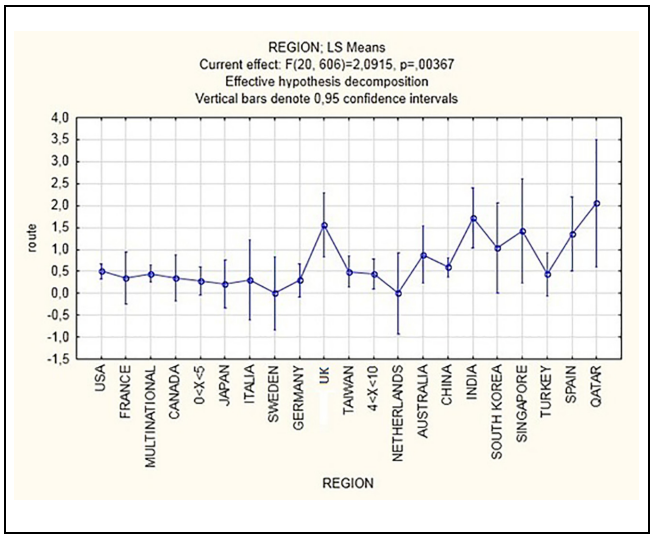

Figure 7. Analysis of variance for regions versus route word.

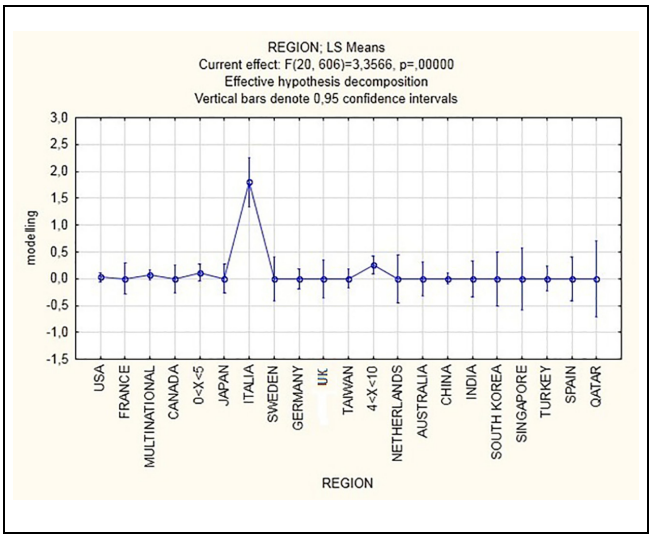

Figure 9. Analysis of variance for regions versus modeling word.

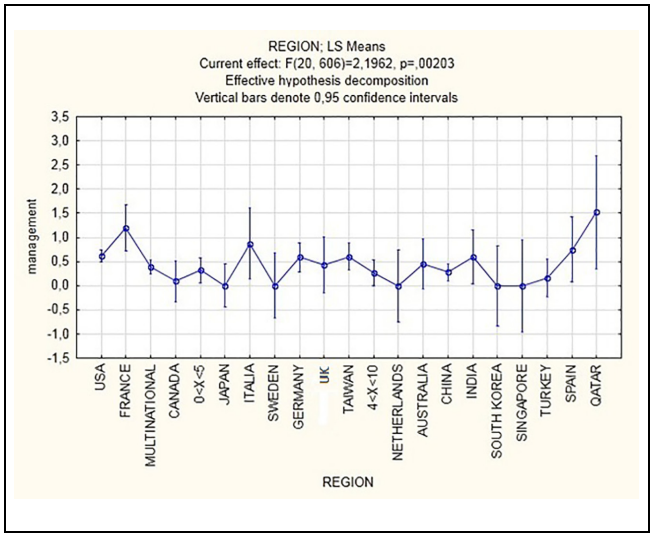

Figure 8. Analysis of variance for regions versus management word.

across the country. The liberalized Indian aviation industry also operates overseas routes. Along with Indian airlines, many foreign airlines combine Indian cities with other major cities in the world. However, although the Mumbai–Delhi air corridor ranks third among the busiest routes in the world, a large part of the country's air transport potential continues to be unused. Many low-cost airlines that entered the Indian aviation market between 2004 and 2005 contributed to this impact.

Qatar's short-term planning and revenue management efforts have led to the need to develop appropriate management styles. To achieve this, it has sought to manage the aviation sector, which is one of the most important income sources in the country. This is clearly shown in Figure 8 which illustrates the short-term revenue management concept when three words are combined. Because it is at the top of the list of the best airlines in the world can also be seen as another proof of its management success.

Aéroports de Paris is one of the government authorities that operates the 14 busiest airports in Paris, including Charles de Gaulle and Orly. For instance, Charles de Gaulle Airport, located near Paris, is the fourth busiest airport in the world with 60.4 million passenger movements in 2015. It is France's primary international airport, serving over 100 airlines. The national carrier of France is Air France, a full-service global airline that flies to 20 domestic destinations and 150 international destinations in 83 countries (including overseas Départments and territories of France) across all six continents. Charles de Gaulle Airport is a center for many European airlines. This has led France to accelerate its work on aviation management to manage the growing demand and expanding demand base.

Figure 9 illustrates how Italy places importance on modeling studies in comparison with other countries. It is known that modeling studies are usually performed under significant constraints and are made to achieve the initial optimal solution. The Italian airline, Alitalia (Linee Aeree Italiane) is the countries, based in Rome.

After Alitalia's bankruptcy in August 2008, Compagnia Aerea Italiana (CAI) acquired the Alitalia brand and some of its assets. The new Alitalia did not retain most of its working fleet; almost every plane was sold or decommissioned, clearing the ground for a new fleet. Alitalia-CAI now generally leases aircraft from Aircraft Purchase Fleet according to its requirements.

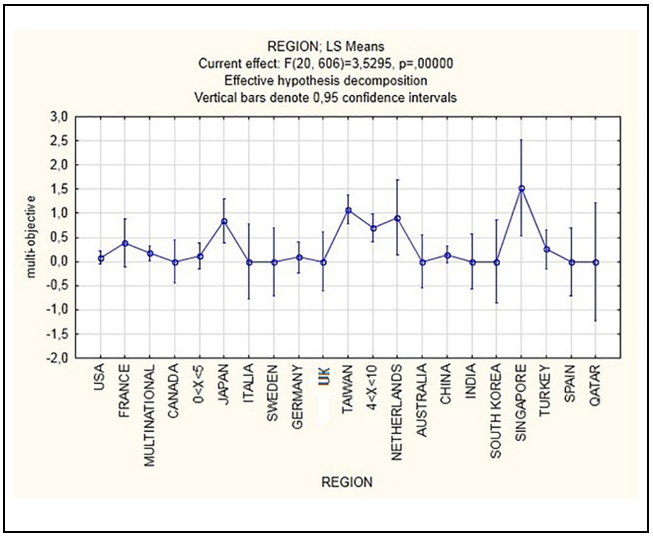

Figure 10. Analysis of variance for regions versus multi-objective word.

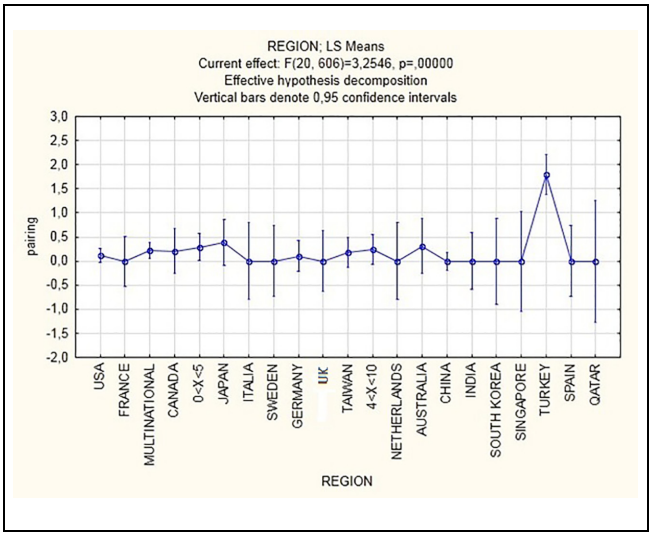

Figure 11. Analysis of variance for regions versus pairing word.

During this process, efforts to determine the priorities of the company and accelerate the use of modeling studies in the decision-making process reflect modeling studies can produce positive results, in this case leading to the creation of a new Alitalia taking on the role of Italy's flag carrier.

Figure 10 presents the relationship between "multi-objective" studies for regions. Aviation in Singapore is a crucial component of the Singaporean economy in its quest to be a transport hub of the Asian region. Currently, the sixth busiest airport and the fourth busiest air cargo hub in Asia, the Singaporean aviation industry is also significant in the fields of aerospace maintenance, repair, and overhaul (*19*). Furthermore, the aviation sector is a major revenue earner for Singapore. Singapore Airlines is the flag carrier airline with its hub at Singapore Changi Airport. It was ranked the world's best airline since 2018, also winning the top spot in three other categories in the same year, including "Best First Class," "Best First Class Airline Seat," and "Best Airline in Asia" (20). Because multi-objective-based studies are mostly conducted in Singapore is likely to result from the city's location. As mentioned, Singapore is one of the biggest maintenance, repair, and overhaul centers in Asia. This is one of the factors that directly affect the income of the aviation industry.

Figure 11 shows the "pairing" related studies for regions. The analysis showed that Turkey is a country that has done a lot of work in the field of pairing. There are a few reasons for this. One is the rapidly increasing population, leading to larger numbers of passengers being carried by airlines and increasing the need for cabin crew. In parallel with this, Turkish Airlines has increased its capacity by growing its fleet. In addition, Pegasus Airlines is a low-cost airline, important in the country as a complement to Turkish Airlines. Since 2018, furthermore, thanks to its geopolitical position between Europe and Asia, Turkey has been assuming the role of a bridge, with both airlines now able to offer a greater network and more destinations. Turkish Airlines still holds the title of airline with the most flight destinations.

Turkish Airlines, which is the country's flag carrier for all these reasons, provided resources to the researchers in performing their studies. As a result, Turkey has a leading position in studies conducted in this area.

In the last of the analyses, "crew," and "scheduling" were examined in the ANOVA as shown in Figure 12. The work carried out in this area is seen most in Sweden and Australia. It is known that aviation is of great importance to Sweden's economy and competitiveness. The basis of Sweden's intensification of its studies on crew scheduling is clearly a state-led strategy. The objective of the Swedish Government's transport policy is to contribute to achieving the lowest unemployment rate in the EU by 2020 (*21*). The Swedish Government states that its export and aviation strategies will provide the conditions to strengthen trade promotion in the Swedish aviation sector. According to OECD reports, Scandinavian Airlines (SAS) had a market share of approximately 70% in the Swedish market for scheduled domestic passenger flights. Further efforts, such as bonuses, to increase the number of passengers in the region will in turn increase the amount of work required for crew scheduling. The development of the Swedish aviation sector brings with it

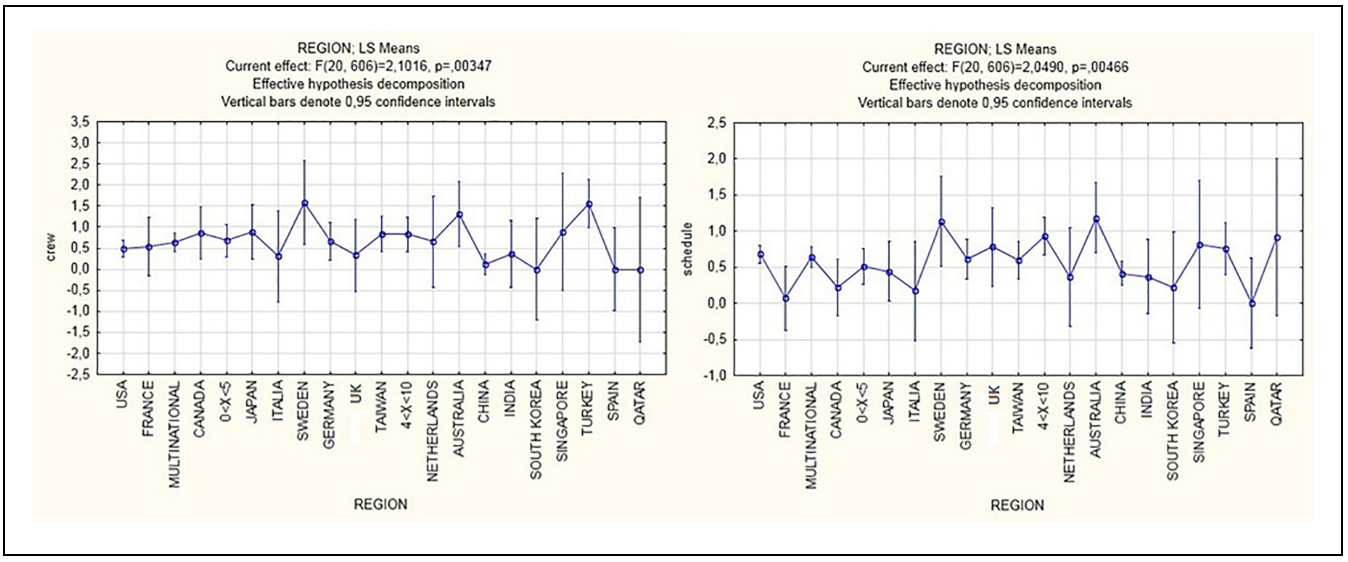

Figure 12. Analysis of variance for regions versus crew and schedule word.

the necessity of regular scheduling and control of both labor and aircraft.

In the case of Australia, the aviation sector is a significant contributor to the economy, adding more than US$30 billion per annum and employing over 250,000 people (*22*). In the report of The Australian Aviation Associations Forum in 2016, it is stated that the industry would require not only large numbers of additional pilots and maintenance staff but also additional air traffic controllers, operations managers, ground handling staff, and other airport staff. Again, one of the most popular strategies—the "à la carte" pricing strategy—which has been followed by most full-service carriers, has increased customer choice and reduced prices for essential services in the UK and Australia (*23*). This situation, which increases customer demand, has increased the number of flights and triggered more work in flight planning and crew scheduling. While Australia is well placed to offer full aviation education opportunities to both domestic and international students, the efforts to further increase the workforce in the aviation sector are being blocked by the Australian regulatory and licensing regime (*23*). To overcome this, Australia accelerated these studies.

Conclusion

The aviation dream, which started with the Wright Brothers, has faced many obstacles over the years. But it has never faded. This study analyzes recent research into developments in airline optimization applications in the aviation sector which has faced several crises and breaking points. It also examines trends and draws inferences. General ideas about the global trends shed light on the future of the aviation sector, which has a significant impact on the economy of many countries. Thus, it is essential to remember that activity today will leave a mark on the future, just as COVID-19 will.

It is reported that airlines face an overall reduction of 51% of seats; 2,867 to 2,897 million passengers; and potential losses in gross passenger operating revenues of US$ 388 to 392 billion (*24*). Many aviation authorities see this as one of the biggest crises in history, making it clear that reducing these effects will only be possible with good and effective planning. The impact of the COVID-19 pandemic on the industry will surely lead to many other trends and protocol changes. In addition, there are still many studies on the future of aviation.

This is described in the IATA's "Future of Airline Industry 2035" report: the importance of emerging markets, economic growth, and the appetite of developing countries for natural resources may increase global prices and make it more challenging to structure supply chains (*25*). It will be possible to overcome these difficulties by restructuring and scheduling airline operations and networks as a primary transportation tool in the supply chain. The development and scheduling of new operation networks will trigger crew scheduling and pairing problems. International political uncertainty and terrorism—what IOTA calls geopolitical instability—will also play an essential role in the selection, scheduling, and development of operational networks. They say that in the next 20 years, state fragility, religious and ethnic problems, and pressure on global resources may trigger conflict (*25*). Even if the problem of supply chain pressure and geopolitical turmoil brought about by changes in the world structure is assumed to be solved, the future shortage of oil presents a new problem. It is known that fossil

fuels cause climatic and geopolitical problems largely because of conflicts of interest in the world.

The aviation industry is one of the flag bearers when it comes to monitoring carbon footprints. In this context, many alternative fuel studies have been carried out. The search for alternative fuels to replace fossil fuels has brought another perspective to the aviation industry. One of these perspectives was to investigate whether a greener airline fleet was possible or not. In this context, this study revealed "Concept 12," in which IATA seeks to answer this question: Can air travel survive in a more sustainable world? Along with these studies, IATA hopes to see a reduction in the amount of carbon dioxide released by fossil fuels into the environment and to prepare the base for a more stable climate. Recently, some airlines have announced that they will support the "Carbon Offset and Reduction Scheme for International Aviation" (CORSIA) from 2020. This statement represents a step toward environmentally friendly aviation with a more stable climate and less carbon dioxide emissions.

Among the aims of this study was to offer an idea for the future of the aviation sector and to contribute to the literature. Some concepts were determined as areas for further work in the aviation sector. The concepts have been determined, examined, and justified in a logical framework.

As a result, more robust and consistent aviation in the future will depend on greater importance being given to airline optimization studies. Environmental factors should be considered, and new methods and technologies developed to minimize environmental damage while continuing airline operations around the world. In the future, greater attention should be paid not only to airline optimization studies but also to any optimization study that avoids waste. As Mustafa Kemal Atatürk said, "The future is in the skies."

Author Contributions

The authors confirm contribution to the paper as follows: study conception and design: Yunus Eroğlu, Metehan Atay; data collection: Metehan Atay; analysis and interpretation of results: Metehan Atah, Yunus Eroğlu, Serap Ulusam Seçkiner; draft manuscript preparation: Metehan Atay, Yunus Eroğlu, Serap Ulusam Seçkiner. All authors reviewed the results and approved the final version of the manuscript.

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Data Availability

The data used in this study is collected from Thomson Reuters—ISI Web of Science database (http://ww.webofknowledge.com) by scanning the studies conducted on airline optimization between the years 1975 and 2018.

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