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A Study on Network Construction Strategies for Long-Haul Low-Cost Carrier Operations*

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Abstract

Purpose – This study aims to analyze the characteristics of network construction by Norwegian Air and AirAsia X, which are recognized as leading airlines in the long-haul LCC market. Based on this analysis, this study intends to provide implications for networking strategies for Korean LCCs that seek to enter the long-haul market when the aviation market stabilizes again upon the end of the COVID-19 pandemic.

Design/methodology – To conduct the network analysis on long-haul low-cost airlines, the Official Airline Guide (OAG) Schedule Analyzer was used to extract long-haul data of Norwegian Air and AirAsia X. To analyze the trend of the long-haul route network, we obtained the data from 3 separate years between 2011 and 2019. The network was analyzed using UCINET 6.0 in order to examine the network structure of long-haul low-cost airlines and the growth trend of each stage.

Findings – Analyzing the network of long-haul routes by visualizing the network structure of low-cost carriers showed the following results. In its early years, Norwegian Air's long-haul route network, centering on regional airports in Spain and Sweden, connected European regions, the Middle East, and Africa. As time passed, however, the network expanded and became steadily strong as the airline connected airports in other European countries to North America and Asia. In addition, in 2011, AirAsia X showed links to parts of Europe, such as London and Paris, the Middle East and India, and Australia and Northeast Asia, centering on the Kuala Lumpur Airport. Although the routes in Europe were suspended, the network continued to expand while concentrating on routes of less than approximately 7,000 km. It was found that instead of giving up on ultra-long-haul routes such as Europe, the network was further expanded in Northeast Asia, such as the routes in Korea and Japan centering on China.

Originality/value – Until the COVID-19 pandemic broke out, Norwegian Air actively expanded long-haul routes, resulting in the number of long-haul routes quintupling since 2011. The unfortunate circumstance, wherein the world aviation market was rendered stagnant due to the outbreak of COVID-19, hit Norwegian Air harder than any other low-cost carriers. However, in the case of AirAsia X, it was found that it did not suffer as much damage as Norwegian Air because it initially withdrew from unprofitable routes over 7,000 km and grew by gradually increasing profitable destinations over shorter distances. When the COVID-19 pandemic ends and the aviation market stabilizes, low-cost carriers around the world, including Korea, that enter the long-haul route market will need to employ strategies to analyze the marketability of potential routes and to launch the routes that yield the highest profits without being bound by distance. For stable growth, it is necessary to take a conservative stance; first, by reviewing the business feasibility of the operating a small number of highly profitable routes, and second, by gradually expanding these routes.

Keywords: Air Transport Industry, Long-Haul LCC, Long Haul Route, Network, Social Network Analysis
JEL Classifications: L93, L11, N70

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1. Introduction

The air transport industry had been one of the fast-growing industries until it suddenly became stagnant due to the recent outbreak of COVID-19. In 2019, the number of people who used air transportation worldwide was over 4.4 billion, which doubled from 2.25 billion in 2009. The average annual growth rate of the global air transport market also steadily increased by 5.3% from 1999 to 2019 (World Air Transport Statistics, 2020).

The most striking aspect about the growth of the air transport industry is the expansion of low-cost carrier (LCC) operations. The LCC market continued to grow and created new demands as it offered attractive prices in conjunction with the increase in travel demands and income levels around the globe. As of 2018, the LCC market share was 31%, indicating that the global growth of the aviation industry was led by LCCs by transporting over 1.3 billion passengers (CAPA, 2019).

Despite such a rapid growth of the LCC market, it is unclear whether it will continue to grow in the future. Although LCCs grew rapidly as they expanded short routes around the globe, it is forecasted that the growth rate of the short-haul market will slow down because the market is saturated.

The competition for short-haul routes primarily targeted by LCCs is becoming intense, saturating the market. Under this circumstance, many global LCCs are making new attempts to enter the long-haul route market, which has been the territory of full-service carriers (FSCs), in an effort to maintain their growth. With regard to the trend of LCCs entering the long-haul route market, Air Asia X first launched long-haul routes in the 2000s in the Asia-Pacific regions, followed by Jetstar. In the 2010s, Norwegian Air, Eurowings, and Westjet launched long-haul transatlantic routes. As LCCs continue to seek and enter into long-haul routes, the number of long-distance LCCs, which was only two airlines AirAsia X and Jetstar until 2011, increased significantly to about 20 airlines in 2018.

In addition, several low-cost carriers around the world are seeking strategies to enter the long-haul market as a new way to achieve and sustain their growth. To this end, they are investigating network construction strategies and the trend of leading airlines to apply them toward route expansion.

Korean LCCs have also achieved rapid growth by expanding short-haul routes, such as Japan and Southeast Asia, but their growth is expected to slow down due to the saturation of the short-haul market. In a situation where competition is intensifying and saturated in the short-haul routes wherein LCCs are the main target, Korean LCCs are also increasing their interest in introducing long-haul business models and routes.

Nonetheless, few studies have been conducted in this field; airlines are taking a greater interest in long-haul LCC operations and the necessity for networking strategy analysis and benchmarking is being highlighted.

In this vein, this study aims to analyze the characteristics of network construction by Norwegian Air and AirAsia X, which are recognized leading airlines in the long-haul LCC market. Based on the analysis, this study intends to present a guideline to help Korean LCCs launch and expand long-haul routes. To achieve the aforementioned objectives, Social Network Analysis (SNA) is utilized in analyzing the characteristics of Norwegian Air and AirAsia X's network building and in examining the steps of Norwegian Air and AirAsia X's network building prior to the outbreak of COVID-19. In addition, this study aims to expound the changing trend and characteristics of the network by examining the LCC airports and the connecting cities, as well as the centrality of the nodes (i.e., airports) and the density of links which Norwegian Air and AirAsia X utilized in building the network. In doing so, this study aims to provide implications for networking strategies for Korean LCCs that seek to enter the long-haul market when the aviation market stabilizes again upon the end of the COVID-19 pandemic.

2. Theoretical Background

2.1. Literature Review of Previous Studies

Previous studies on long-haul LCC and airline networks were reviewed. First, studies on long-haul LCCs mainly examined the viability, feasibility, profitability, and sustainability of long-haul LCC model as a new business model. One of the early studies on long-haul LCCs was conducted by Morrel (2007), who questioned the feasibility of long-haul LCCs due to the difficulty in gaining a cost advantage. However, other scholars such as Pels (2008), Moreira et al. (2011), and Daft and Albers (2012) later reported the expanding trend of the long-haul LCC model, drawing positive conclusions regarding the viability and feasibility.

Moreira et al. (2011) analyzed the aircraft-related operating costs of legacy carriers and LCCs to examine the viability of long-haul LCC operations. For this, they performed a cost simulation involving the use of a Boeing 767-300 fleet by an LCC and a legacy carrier, under varying operating conditions based on flight distance, and presented the cost advantage of long-haul LCCs over legacy carriers.

Poret et al. (2015) analyzed the operating costs involving a transatlantic flight using the newest Boeing 787 fleet to determine the economic viability of long-haul LCCs. They pointed out the fact that the demand and fuel price can affect economic viability and addressed the need for a networking strategy to connect with a highly desired market to ensure the stable economic viability.

Soyk et al. (2017) conducted a factor analysis and class analysis based on the data from transatlantic airlines, to investigate characteristics, profitability, and sustainability of the long-haul LCC business model, which is increasing in the North Atlantic market. According to their analysis, the long-haul LCC business model differed from legacy carriers and leisure airlines in terms of point-to-point route, use of a secondary airport, use of an efficient mechanism, and omission of a bundled package. In terms of costs, the long-haul LCC business model was found to be sustainable because it spends 30% less than legacy carriers and leisure airlines.

In addition, although studies analyzing the network of long-haul LCCs have not yet been conducted, some scholars investigated the structure of the aviation network. Wang et al. (2011) performed a network analysis to examine the structure and characteristics of the airport network in China. They analyzed the centrality of Chinese airports in terms of degree centrality, closeness centrality, and betweenness centrality, and described the network of Chinese airports as that of “a small world”. They also mentioned that three types of centralities are highly related to socio-economic indicators i.e., the air passenger volume, population, and gross regional domestic product (GRDP).

Wittman and Swelbar (2014) computed the connectivity scores for 462 airports in the U.S.

from 2007 to 2012. They discovered that small-hub and medium-hub airports lose network connectivity at a greater level than large-hub airports and highlighted the importance of employing strategies to vitalize the small-to-medium hubs to develop the air transport industry and improve network connectivity.

Jia et al. (2014) analyzed the evolution of the U.S. airport network from 1990 to 2010 and examined the characteristics of change in multiple aspects such as the number of cities and routes, flight frequency, passengers, and freight. They stated that the U.S. aviation network grew in terms of structure and air traffic volume in 2002 despite the decrease in the number of air passengers. Regarding reasons for this, they mentioned that the government's decision to diversify alternative air routes, as a countermeasure for major airports being paralyzed during terrorist attacks (such as the September 11 attacks), stimulated the construction of new airports to make air transportation more robust and flexible. The U.S. aviation network is characterized by power law distribution and its resemblance to a small world. They found that the operation of new airports which had newly appeared on the network after 2002 had declined again, whereas the operation of airports at stable cities showed a structural regularity over time.

Hossain and Alam (2017) analyzed the structure and characteristics of networks using network tools for domestic air routes in Australia. Networks were identified using connection distribution, path length, clustering coefficient, and centrality indicators, and through this, Australia's aviation network was found to have the "small world" attribute similar to that of airport networks in China and India.

Jiang et al. (2017) performed a statistics analysis and network analysis to examine the network structure and characteristics of low-cost carriers in China. They selected Spring Airlines as the target of analysis and examined the data on the connecting airports, air routes, and the aviation network development process from 2005 to 2013. They discovered that the early network formed a star-shaped structure, with Shanghai airport in the center, connecting tourist destinations as opposed to provincial airports. Later, the network began to develop multiple hubs.

Cheung et al. (2020) proposed a Global Airport Connectivity Index (GACI) by calculating connection, proximity, and eigenvector centrality indicators for transportation networks at global airports from 2006 to 2016. In addition, it was found that the speed of increase in passengers at large airports with an improved connectivity index was higher than at other airports. In addition, the U.S. and Northern Asia have focused on developing regional hubs from short to medium-haul routes, while Western Europe, Southeast Asia, and the Middle East have focused on developing major airports as global hubs. It was also found that an increase in the connectivity index improves the competitiveness of airports and increases their influence on other airports.

Rodrigo et al. (2021) analyzed the network structure and centrality of seven major airports in Brazil by period using social network analysis (SNA). From 2003 to 2020, passenger data for each airport was collected by five periods, and networks were established and centrality and density were analyzed using Ucinet and Netdraw. Due to this, it was analyzed that in the process of forming the hub-and-spoke network, the connection of links and nodes was developed by Brasília Airport in the central west region of Brazil and São Paulo and Rio de Janeiro Airports in the southeast region. In addition, as a result of analyzing the Covid-19 pandemic period of 9 months in 2020, it was analyzed that both the centrality and density of these seven airport networks decreased.

Prabhakar and Anbarasi (2021) used SNA to analyze the structure and pattern of the international aviation networks and to analyze airports with centrality. Airports with high centrality, such as Paris CDG, London Heathrow, and Dubai, were identified using several centrality indicators such as degree centrality, betweenness centrality, and eigenvector centrality. And by calculating the clustering coefficient and the average shortest part of the network, it was explained that the global airport network has the characteristics of a small world network. In addition, it was explained that some regional networks such as France and India have both the functions of small world and scale-free networks.

As such, many scholars conducted studies on long-haul LCCs and aviation networks by using a variety of methods to analyze the viability, feasibility, and profitability of long-haul LCCs, as well as the aviation network structures in terms of regions, airports, and cities. Previous studies on long-haul LCCs focused on the aspects of viability, profitability, and sustainability. By contrast, the present study selected the long-haul LCC network as the main target of analysis. While previous studies on aviation networks focused on airports, the present study selected the network of an airline as a target of analysis. To be specific, we selected the network of long-haul routes that LCC airlines are taking, to examine the detailed property of the airline network building, by analyzing the changes in the network in terms of connectivity between airports and links. This study aims to utilize the Social Network Analysis (SNA) method for the analysis of the characteristics of the aviation network operated by long-haul low-cost carriers. In this manner, this study can be differentiated from previous studies on long-haul LCCs or an airport-centered network analysis.

In addition, considering that the previous studies related to long-haul LCC have been focused on the viability, feasibility, profitability, and sustainability of long-haul LCC, this study aims to compare and analyze the network construction characteristics of Norwegian Air and AirAsia X using SNA. It is judged that it can be used as a useful reference material in the process of entering and building long-haul routes by Korean LCCs while broadening the scope of long-haul LCC research.

2.2. Social Network Analysis and Centrality Indices

2.2.1. Social Network Analysis (SNA)

Using SNA helps understand the characteristics of an entire network from a new perspective, on certain phenomena, by analyzing the structure connected by points and lines (i.e., nodes and links) and the relationship between them.

SNA is a method which involves quantitatively structuring the relationship between individuals and groups as nodes and links and analyzing their characteristics by focusing on the relationships among social entities and the effects of relationships and patterns. From the perspective of SNA, social environment can be described as a type of relationship or a regular pattern between interacting units. The regular pattern emerging in this relationship is called structure, and SNA mainly aims to understand the network structure (Wasserman and Katherine, 1994).

Recently, SNA has been recognized as a primary methodology for complexity science in various academic fields, and is used not only in the field of social science covering general social phenomena, but also in research on international politics, international relations, international trade and logistics (Tabassum et al., 2018). These fields of studies analyze the centrality of each node, the link pattern, and network characteristics, and compare various indicators such as society, organization, and economy, and then use them for assessing competitiveness. As such, network science is seen as a new approach or tool for observing social phenomena, particularly complex social occurrences or complexity, which could not be easily understood in the past. The ultimate goal of network science is to identify the relationship between the analyzed entities and to understand the structure or change in complexity based on such relationship.

Network science has recently been applied to the field of airport and aviation network research and is being used to examine the characteristics of aviation network construction and change, or to compare the importance of airports. Network science has the advantages of mathematically clearing the complex real world as well as visually presenting it. And this advantage makes it possible to understand the characteristics of the network of the complex aviation market in the field of aviation-related research and to analyze the capabilities of airports as well (Rodrigo et al., 2021).

Using the graph theory, a branch of mathematics, the network can be expressed as G={N, L, f}: G as a network; N as a set of nodes; and L as a set of links. Here, f can be defined as an N×N link function which describes how nodes are connected through each link.

2.2.2. Network Centrality Indices

In SNA, the centrality indices can be classified into degree centrality, closeness centrality, betweenness centrality, and eigenvector centrality.

Degree centrality is an indicator of centrality that focuses on the nodes connected between points, which measures the number of nodes connected to each individual node. The node with more connected nodes exhibits a higher degree centrality (Freeman, 2004). The number of inbound links toward one node is called in-degree centrality, and the number of outbound links toward one node is called out-degree centrality. The equation for computing the degree centrality is as follows.

$$C_D(i) = \sum_{j=1}^{n} a_{ij} \tag{1}$$

Closeness Centrality conceptualizes how close one node is to other nodes. In other words, it shows how short the path is from one node to all the other nodes. Normally, the shorter the path is to the other nodes, the higher the centrality becomes. It is highly probable for nodes with a higher closeness centrality to impact other nodes or to be impacted by other nodes most quickly (Ayman et al., 2020). The equation for computing the closeness centrality of node i is as follows.

$$C(i) = \frac{n-1}{\sum_{vi \in V,\, i \neq j} d_{ij}} \tag{2}$$

Betweenness centrality is the measure of centrality focusing on certain nodes that play the role of a 'bridge' in a network (Valeri and Baggio, 2020). In other words, it determines whether one node performs the role of a broker with other nodes in building the network. The nodes which are more likely for other nodes to pass have a higher betweenness centrality. $C_B(i)$ is the betweenness centrality of node i, and it is expressed in the percentage of the shortest paths through the node. $g_{jk}(i)$ refers to the number of the shortest links between two certain points (j and k). In other words, $g_{jk}(i)$ refers to the number of links between two points, j and $k(j \neq k)$ that pass through the point i. The equation for computing the betweenness centrality is as follows.

$$C_B(i) = \sum_{j<k}^{n} g_{jk}(i)/g_{jk} \tag{3}$$

Eigenvector centrality is the concept used to evaluate the influence or significance of one node. It takes into account the centrality of one node as well as the centrality of other nodes connected to such node (Serrat, 2017). Eigenvector or power centrality highlights the central node which has a great impact within the network. In other words, eigenvector centrality is an indicator that shows a node's possibility of increasing influence when it is connected to a node with a relatively high centrality (Saqr et al., 2018). As for the aviation network, the airports with a higher eigenvector centrality are connected to many other airports within the network, and such numerous connections are interpreted as indicative of a higher probability of increasing the volume of passenger transport.

The equation for computing eigenvector centrality is shown in Equation 4 as follows: x_i as the score of node i; $M(i)$ as the set of all nodes connected to node i; λ as a constant; and N as the set of all nodes.

$$x_i = \frac{1}{\lambda} \sum_{j \in M(i)} x_j = \frac{1}{\lambda} \sum_{j=1}^{N} a_{ij} x_j \tag{4}$$

3. Method of Data Collection and Analysis

3.1. Data Collection

This study aims to analyze the characteristics of network construction by Norwegian Air and AirAsia X, which are recognized leading airlines in the long-haul LCC market. According to a survey of the total number of routes and seat supplies for long-haul LCC airlines as of 2017, the number of routes out of 17 airlines was found to be in the order of Norwegian Air (48) and AirAsia X (21). And the seat supply of these airlines was also found to be the largest (CAPA, 2018).

To conduct the network analysis of long-haul low-cost airlines i.e., the main objective of this study, the Official Airline Guide (OAG) Schedule Analyzer was used to extract the long-haul data of Norwegian Air and AirAsia X. The OAG Schedule Analyzer comprises the Market Information Data Tapes (MIDT), which were created based on the flight schedules and reserved ticket information for each airline. To analyze the trend of the long-haul route network for this study, we obtained the data from 3 separate years: 2011, the year when the airlines launched long-haul routes; 2015, the year of steady growth; and 2019, the year before the COVID-19 pandemic affected the airlines.

Table 1. Basic statistical analysis of long-haul routes

Airline	Year	Number of routes	Total number of flights (one-way)	Average number of flights (one-way)	Average flight distance (one-way, km)
Norwegian Air	2011	18	838	47	4,427
	2015	48	3,398	70	6,299
	2019	91	12,366	136	6,876
AirAsia X	2011	17	4,214	247	5,897
	2015	22	6,883	313	4,787
	2019	28	9,392	335	4,579

Source: The author's recap of OAG Schedule Analyzer data.

In this study, we used the annual number of flights of Noregian Air and AirAsia X. We selected the long-haul LCC routes longer than 4,000 km as the target of network analysis of Norwegian Air. According to the European Organisation for the Safety of Air Navigation (Eurocontrol), long-haul routes are longer than 4,000 km, medium-haul routes are between 1,500 km and 4,000 km, and short-haul routes are shorter than 1,500 km. In the case of AirAsia X, routes over 3,000 km, which are separated from AirAsia and divided into long-haul routes and operated intensively, were analyzed.

By acquiring the OAG data for long-haul routes operated by Norwegian Air and AirAsia X, we performed a basic statistical analysis. The results showed that Norwegian Air operated 18 long-haul routes in 2011, 48 long-hault routes in 2015, and 91 long-haul routes in 2019, just before the outbreak of the COVID-19 pandemic. In addition, the average number of flights per route increased from 47 in 2011, to 136 in 2019, and the average flight distance per route also increased from 4,427 km to 6,876 km due to the increase in the number of longer routes.

AirAsia X operated 17 long-haul routes in 2011, 22 long-haul flights in 2015, and 28 long-haul flights in 2019, and the average number of flights per route increased from 247 to 335. However, the average flight distance was reduced from 5,897 km to 4579 km, in contrast to Norwegian Air.

3.2. Analysis Method

To examine the change in the network density of long-haul routes, we performed a density analysis based on data from the years 2011, 2015, and 2019. Density is the ratio of the actual connections to the total number of potential connections. A high density indicates that there are many connections in the network. A low density indicates that the airline focuses on a small number of connections (Jiang et al., 2017)

In the case of Norwegian Air, from 2011 to 2019, the number of nodes (airports) increased from 14 to 51, and the number of links between airports was 182. The density increased from 46.6 in 2011, to 70.8 in 2015, and 136.6 in 2019, indicating that there were more connections between nodes than the number of increased nodes. In the case of AirAsia X, the number of nodes increased to 18 in 2011, 23 in 2015, and 28 in 2019. The number of links between airports increased from 34 to 56. The density increased from 247.7 in 2011 to 305.4 in 2015 and 301.8 in 2019, indicating that there are more connections between nodes than in 2011. The result of comparing the network density is shown in the table below.

Table 2. Comparison of network density by year

Airline	Year	Number of nodes	Number of links	Density
Norwegian Air	2011	14	36	46.556
	2015	27	94	70.787
	2019	51	182	136.611
AirAsia X	2011	18	34	247.735
	2015	23	44	305.409
	2019	28	56	301.857

To examine the network structure of long-haul low-cost airlines and to analyze the growth trend of each stage, we used UCINET 6.0, a network analysis program. Unlike the fragmentary values derived from the existing statistical data analysis, this method of network analysis allows a researcher to structurally analyze the network based on the premise that the separate nodes and connecting links have interaction, influence, and patterns (Chang, 2018). In this study, we used UCINET to examine the change in centrality and density of long-haul routes by structuralizing the main nodes and lines of the long-haul route network and by analyzing the centrality of each node. As centrality indices, we used the degree centrality and eigenvector centrality, which are frequently utilized in network analysis.

4. Network Analysis of Long-haul Routes

4.1. Network Analysis by Year

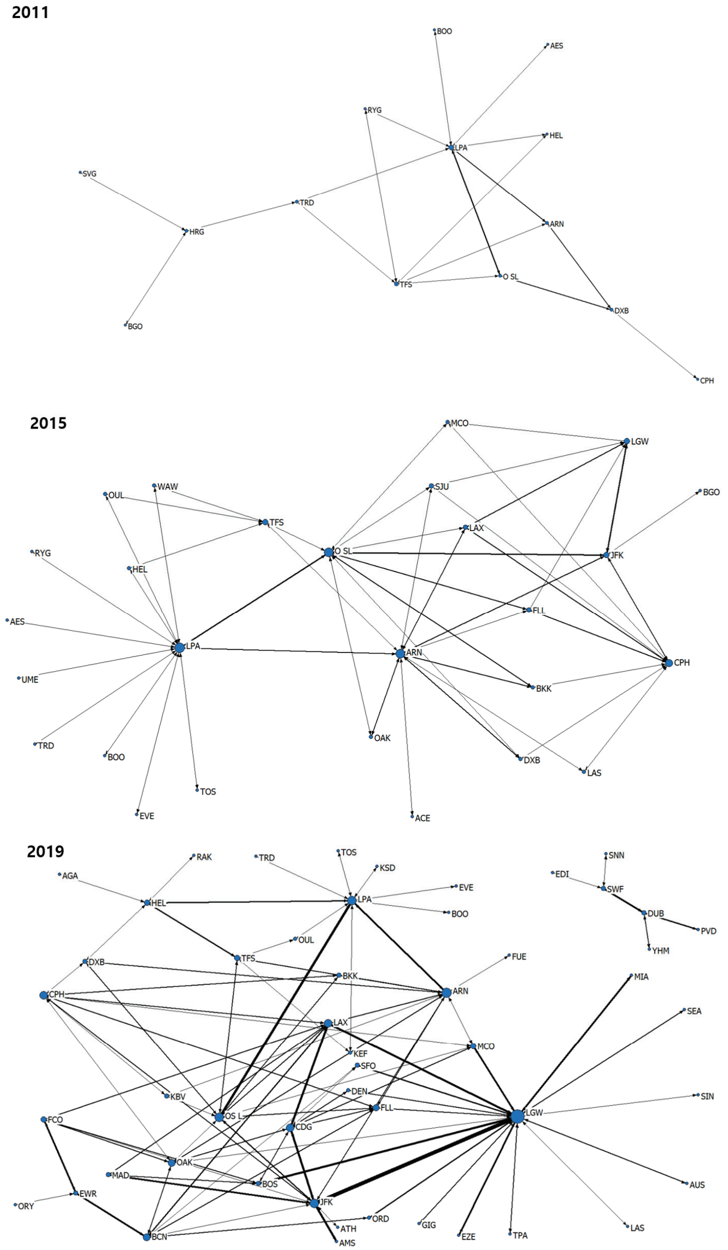
To examine the structure of the long-haul LCC network, we created a metric of long-haul routes by year and visualized the network using UCINET as shown in Fig. 1.

Norwegian Air's long-haul route network was found to have 14 nodes and 36 links in 2011. The network also showed the connection between European regions centering on the Gran Canaria Airport in Spain (LPA), Oslo Airport in Norway (OSL), and Stockholm Arlanda Airport in Sweden (ARN) to Middle East Asia and Africa. In terms of density of the links, the routes with the highest number of flights were found to be Spain (LPA)~Norway (OSL), followed by Sweden (ARN)~Spain (LPA), Dubai, United Arab Emirates (DXB)~Norway (OSL), Dubai (DXB)~Sweden (ARN), and Norway (OSL)~Tenerife, Spain (TFS).

In 2015, 27 nodes were connected by 94 links, which shows an expansion of the network structure compared to that of 2011. In addition, the network showed the utilization of a greater number of provincial airports, such as those in Gatwick in London (LGW), Copenhagen in Denmark (CPH), and New York in the U.S. (JFK), than the past, actively connecting European regions to North America and Asia.

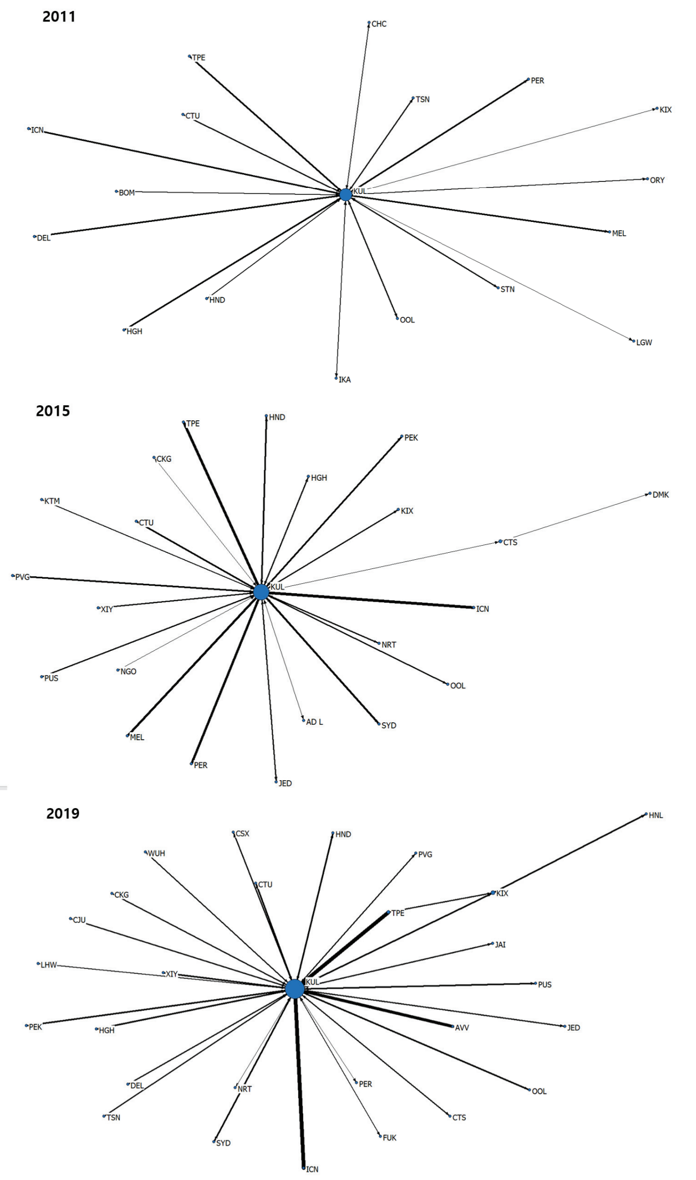
In addition, up until the COVID-19 breakout, the network had steadily expanded to 51 nodes with 182 links, by quintupling the routes compared to 2011. In the network, the Gatwick Airport in London was used as the main hub, and other major airports, such as those in Gran Canaria in Spain (LPA), Stockholm Arlanda in Sweden (ARN), and Oslo in Norway (OSL), were utilized more frequently. In addition, the network expanded and became steadily strong as the airline connected many other regional airports of EU member countries (such as the Oakland International Airport in the U.S. (OAK) and the Dublin airport in Ireland (DUB) to North America and Asia. In terms of the density of links, the routes with the most flights were found to be London (LGW)~New York (JFK), Spain (LPA)~Norway (OSL), Los Angeles, U.S. (LAX)~London (LGW), Charles de Gaulle, France (CDG)~LA (LAX), and France (CDG)~New York, U.S. (JFK).

Fig. 1. Change in the network structure of Norwegian Air



In the case of AirAsia X's long-haul routes, there were 18 nodes and 34 links in 2011, 23 nodes and 44 links in 2015, and 28 nodes and 56 links in 2019. It was found that AirAsia X was connecting long-haul routes by using the Kuala Lumpur Airport as its main hub in the same manner as the Malaysia Airlines, a regional rival FSC. From this, it was found that AirAsia X entered the market with direct competition, considering Malaysia Airlines, when entering the initial long-haul route, even though it was an LCC.

Fig. 2. Change in network structure of AirAsia X



Although AirAsia X initially lacked networks in number, as compared to Malaysia Airlines which is a regional rival FSC, it has been shown to connect parts of Europe, the Middle East and India, and Australia and Northeast Asia, centering on Kuala Lumpur Airport in Malaysia. The strength of the link was analyzed as the strongest in descending order of Kuala Lumpur-Melbourne in Australia (MEL), Taoyuan in Taiwan (TPE), Perth in Australia (PER), Incheon in Korea (ICN), and Delhi in India (DEL). And although routes in Europe were cut off in 2019, it was found that the network is further increasing in Northeast Asia, in countries such as Korea and Japan, centering on China, and is building an expanded network by connecting Hawaii Honolulu (HNL). Initially, there were some routes of more than 10,000 km, including London's Gatwick (LGW), London's Stanstead (STN), and Paris' Orly (ORY) Airport. However, these routes were reduced and the number of 3,000 to 5,000 km routes was greatly increased. Most of them were shown to be operating long-haul networks with routes less than 7,000 km.

4.2. Centrality Analysis of Long-haul Routes

To further examine the nodes that Norwegian Air and AirAsia X utilized in launching long-haul routes, we conducted a centrality analysis. According to the result of the centrality analysis on long-haul routes of Norwegian Air, the London Gatwick Airport (LGW) was found to have the highest out-degree centrality in 2019, followed by the airports in New York (JFK), Los Angeles (LAX), Oslo (OSL), and Charles de Gaulle (CDG).

In 2011, the airports with the highest centrality were located in Spain, Norway, and Sweden. In 2019 however, these airports were no longer on the top because the airports in the U.S., the U.K., France, and Italy arose in centrality. This indicates that the long-haul route network expanded, connecting many more European regions to North America.

Table 3. Centrality scores of long-haul routes of Norwegian Air

Classification	Year 2011		Year 2015		Year 2019	
Rank	**Airport**	**NOutDeg**	**Airport**	**NOutDeg**	**Airport**	**NOutDeg**
1	LPA	0.147	OSL	0.141	LGW	0.084
2	OSL	0.126	ARN	0.133	JFK	0.058
3	ARN	0.083	JFK	0.123	LAX	0.035
4	DXB	0.069	LPA	0.087	OSL	0.033
5	TFS	0.050	CPH	0.083	CDG	0.031
6	TRD	0.022	LGW	0.068	ARN	0.027
7	HEL	0.015	LAX	0.065	LPA	0.027
8	CPH	0.010	BKK	0.047	BCN	0.019
9	HRG	0.009	FLL	0.039	BOS	0.016
10	RYG	0.008	DXB	0.030	FCO	0.015
Rank	**Airport**	**Eigenvector**	**Airport**	**Eigenvector**	**Airport**	**Eigenvector**
1	LPA	0.619	JFK	0.491	LGW	0.582
2	OSL	0.604	OSL	0.426	JFK	0.537
3	ARN	0.342	ARN	0.382	LAX	0.276
4	DXB	0.286	LGW	0.305	BOS	0.256
5	TFS	0.189	CPH	0.279	OSL	0.184
6	DXB	0.174	LPA	0.272	MCO	0.157
7	HEL	0.067	LAX	0.252	MAD	0.146
8	RYG	0.032	BKK	0.210	EZE	0.143
9	CPH	0.029	FLL	0.183	AMS	0.140
10	AES	0.003	DXB	0.135	MIA	0.133

In addition, the airports that were not top-ranked in 2011 (those in Gatwick, Los Angeles, Charles de Gaulle, Barcelona, Boston, and Rome) became major airports in 2019. This indicates that Norwegian Air continued to expand the network, discovering new destinations.

As an index that considers the degree centrality of a node as well as the significance of other connected nodes, the eigenvector centrality measures the significance and influence of one node. In terms of the eigenvector centrality, Gran Canaria in Spain , Oslo in Norway, Stockholm in Sweden, Dubai in the United Arab Emirates and Tenerife in Spain ranked highly in the early years. In 2019, however, other airports such as those in London in the U.K., Los Angeles, Florida, and Boston in the U.S., and Madrid in Spain arose as the top airports. This indicates that these airports had become major airports connecting long-haul routes and had built a close connection with other major airports, while significantly expanding long-haul routes. In other words, as the eigenvector centrality index indicates, these airports grew to be the airports with influence and significance in the long-haul route market.

In the early years, Norwegian Air's long-haul route network centered on regional airports in Europe (such as those in Gran Canaria in Spain, Oslo in Norway, Stockholm Arlanda in Sweden) connecting some regions in Middle East Asia and Africa. However, as time passed, the network expanded and became steadily strong as the airline connected the airports in other EU member countries (such as the London Gatwick Airport in the U.K., Charles de Gaulle Airport in France, and Amsterdam Schiphol Airport in the Netherlands) to North America and Asia.

Norwegian Air initially built a long-haul route network in a very simple manner, using airports in Spain and Norway. However, over time, multiple airports such as those in London, Spain, Sweden, and Norway were used as main hubs to connect more diverse regions such as North America and Asia. It can be inferred that Norway Air's network has changed from a simple network to a hybrid network in which multiple hub-and-spoke systems and point-to-point systems are combined.

Table 4. Centrality scores of long-haul routes of AirAsia X

Classification	Year 2011		Year 2015		Year 2019	
Rank	**Airport**	**NOutDeg**	**Airport**	**NOutDeg**	**Airport**	**NOutDeg**
1	KUL	0.069	KUL	0.418	KUL	0.324
2	MEL	0.059	TPE	0.045	TPE	0.044
3	TPE	0.057	ICN	0.044	ICN	0.037
4	PER	0.054	MEL	0.039	KIX	0.037
5	ICN	0.052	PER	0.035	AVV	0.030
Rank	**Airport**	**Eigenvector**	**Airport**	**Eigenvector**	**Airport**	**Eigenvector**
1	KUL	0.707	KUL	0.707	KUL	0.702
2	MEL	0.254	TPE	0.298	TPE	0.340
3	TPE	0.244	ICN	0.291	ICN	0.330
4	PER	0.234	MEL	0.255	AVV	0.267
5	ICN	0.225	PER	0.231	KIX	0.173

In the case of AirAsia X, in 2011, the centrality of airports in Kuala Lumpur in Malaysia, Melbourne in Australia, Taoyuan in Taiwan, Perth in Australia, and Incheon in Korea was very high. In 2019, the rankings of airports in Kansai in Japan and Melbourne in Australia rose along with slight changes in rankings in Kuala Lumpur, Taoyuan, and Incheon. In addition, considering that the centrality of these top airports has decreased and been distributed compared to 2011, AirAsia X was found to have connected more airports by discovering more destinations amid the expansion of the network.

AirAsia X's long-haul network was initially centered on Kuala Lumpur Airport, connecting parts of Europe and the Middle East, and Australia and Northeast Asia. However, over time, instead of eliminating routes in Europe and New Zealand over 7,000 km, it transformed into a network that expands and shows a strong flow centered on a section of 3,000 to 5,000 km, connecting airports in Korea and Japan, centering on China.

Since 2011, AirAsia X's network has been steadily expanding with the airport in Kuala Lumpur as its main hub. Further, AirAsia X's network can be said to be more of a hub-and-spoke system, similar to that of Malaysia Airlines, a regional FSC. It is expected that it can play a role in effectively linking long-haul routes by linking with the routes of its parent company i.e., AirAsia's short-haul routes.

5. Conclusion

In recent years, due to the active development and launching of short-haul routes by low-cost carriers, the global aviation market has become saturated with short-haul routes. To maintain a steady growth rate, many LCCs around the globe are making new attempts to enter the long-haul route market, which was the main territory of FSCs in the past.

This study aimed to analyze the characteristics of the network building of Norwegian Air and AirAsia X, which are recognized as leading airlines in the long-haul LCC market. Based on the analysis, this study strived to present a guideline to help Korean LCCs to launch and expand their long-haul routes.

To conduct the network analysis on the low-cost carriers' long-haul routes, we extracted Norwegian Air and AirAsiaX's long-haul route data from OAG Schedule Analyzer, and analyzed the data in units of three years.

To analyze the long-haul route network, we visualized the structure of the network of low-cost carriers. The analysis of Norwegian Air showed the following results. In the early years, the network centered on Gran Canaria in Spain, Oslo in Norway (OSL) and Stockholm Arlanda in Sweden connecting European regions, Middle East and Africa. Until the outbreak of COVID-19, the routes steadily increased by five times compared to 2011. The Gatwick Airport in London was used as a main hub, and well-established major airports, such as those in Gran Canaria in Spain, became more vitalized. In addition, by utilizing many more regional airports such as the Charles de Gaulle Airport in France, Oakland International Airport in the U.S. (OAK), and the Dublin airport in Ireland, the network expanded and became strong as it connected many more EU countries with North America and Asia.

The centrality analysis on long-haul routes resulted in the following findings. In 2011, the main airports in Spain, Norway, Sweden, and the United Arab Emirates were found to have the highest centrality, but in 2019, the rank of these airports changed and airports located in other countries such as the U.S., the U.K., France, and Italy gained a high centrality level. This indicates that the network of long-haul routes grew, connecting many more regions in European and North America.

The analysis of Eigenvector centrality index exhibited the following results. In early years, airports located in Norway, Sweden, Spain, and Dubai were ranked highly, but in 2019, the airports in London in the U.K., Madrid in Spain, and several cities in the U.S. rose to the top. This indicates that these airports became major airports for long-haul routes, forming a close connection with other major airports, while significantly expanding their network.

In the early years, Norwegian Air's long-haul route network centered on the airports in Spain, Norway, and Sweden, connecting some regions in Middle East Asia and Africa. However, as time passed, the network expanded and became steadily strong as the airline connected the airports in other EU member countries (such as the London Gatwick Airport in the U.K., Charles de Gaulle Airport in France, and Amsterdam Schiphol Airport in the Netherlands) to North America and Asia.

Norwegian Air initially built a long-haul route network in a very simple manner using airports in Spain and Norway. However, over time, multiple airports such as those in London, Spain, Sweden, and Norway were used as main hubs to connect more diverse regions such as North America and Asia. It can be inferred that Norway Air's network has changed from a simple network to a hybrid network in which multiple hub-and-spoke systems and point-to-point systems are combined.

Although AirAsia X was initially smaller than Malaysia Airlines, a regional competitor, AirAsia X exhibited links to parts of Europe such as London and Paris, the Middle East and India, and Australia and Northeast Asia, centering on the Kuala Lumpur Airport. In addition, although the routes in Europe over 10,000 km were suspended, the network continued to expand by approximately 1.6 times while concentrating on routes of less than 7,000 km. It was found that instead of giving up on ultra-long-haul routes such as Europe, the network was further expanded in Northeast Asia, in countries such as Korea and Japan, centering on China, and a further expanded network was established by connecting Hawaii.

Since 2011, AirAsia X's network has been steadily expanding with the Kuala Lumpur Airport as its main hub. AirAsia X's network can be said to be more of a hub-and-spoke system, similar to that of Malaysia Airlines, a regional FSC. Further, it is expected that it can play a role in effectively linking long-haul routes by linking with the routes of its parent company i.e., AirAsia's short-haul routes.

This is in stark contrast to Norwegian Air's network expansion strategy. In Norwegian Air's case, the airline actively expanded its long-haul routes by five times within 8 years from 2011 to 2019. Unfortunately, however, aviation market became stagnant due to the outbreak of COVID-19. Under this circumstance, Norwegian Air suffered more than any other low-cost carriers. However, in the case of AirAsia X, it was found that it did not suffer as much damage as Norwegian Air because it initially withdrew from unprofitable routes of over 7,000 km and grew by gradually increasing profitable destinations over shorter distances.

Korean LCC airlines have also been interested in expanding long-haul routes for new growth in line with the saturation of the short-haul market. In fact, Jin Air flew directly to long-haul routes such as Honolulu, Hawaii, and Cairns, Australia, from 2015 until the outbreak of COVID-19. Jin Air is the only LCC in Korea to have 4 wide-body aircraft with 393 seats. Jin Air owns four B-777 aircraft, which are large aircraft, with a maximum flight distance of 12,610km. In 2017, Jin Air announced plans to introduce new aircraft to Eastern European routes such as Budapest, Hungary and Zagreb, Croatia.

T'way Air plans to introduce a total of three A330-300 aircraft from February to May 2022 and start operating on mid to long-haul routes. The A330-300 is a mid-to-large aircraft that can operate up to 11,795 km, and can operate two types of seats, business class and economy class, by utilizing its wide size. T'way Air is now able to expand its destinations to Eastern

Europe, North America, Australia and Central Asia, which could not be operated with the existing B737-800 aircraft. In addition, Jeju Air and Air Busan also tried to enter long-haul routes by introducing new, highly efficient, narrow-body models of the Boeing 737-max with a maximum operating distance of 6,570 km and the Airbus 321LR with a maximum operating distance of 7,400 km. However, due to COVID-19, the timing of the introduction is currently being adjusted.

In the case of Korea's LCC, it is thought that the gradual expansion of routes within 7,000 km, such as AirAsia X's network establishment, will help the stable expansion of routes. To this end, the strategy of entering a route within 6,000 km through the introduction of new narrow-body aircraft, such as the B-737 max or Airbus 321LR, is also thought to be very helpful in enhancing competitiveness. Since these aircraft are the same models as existing aircraft, they also have the advantage in decreasing the burden of training for piots and equipment, so it is judged that they will be able to enable a more stable entry. And when introducing large aircraft in the future, it will help to strengthen competitiveness if medium and large models with high efficiency such as the A330-300 and Boeing 787 are introduced to reduce fuel costs and offer lower fares through more efficient seating arrangement.

In our view, once the COVID-19 pandemic ends, the aviation market will become stable and the short-haul route market will be saturated again. At that point in time, low-cost airlines around the world, including those in Korea, will explore ways to enter the long-haul market. However, for stable growth after entering the long-haul route market, it is necessary to analyze the marketability of routes without being bound by the distance of 10,000 km, select the most profitable routes first, and gradually expand the routes from a conservative perspective.

This study visualized the structure of a long-haul route network of a low-cost carrier and performed a centrality analysis. These findings can be utilized to understand the overall structure of the long-haul route network and to identify the stage of airport utilization. Nonetheless, this study has limitations in that the target of analysis was limited to Norwegian Air and AirAsia X's routes and that a more in-depth comparative analysis was not carried out among the long-haul routes of the world's major long-haul LCCs as a comparison group. Therefore, a follow-up study on long-haul routes of a large number of major long-haul LCCs in the world can be conducted in the future. In doing so, the characteristics and strategies of long-haul routes can be identified more specifically.

References

Ayman, N., Gharib, T.F., Afify, Y. and Hamdy, M. (2020), "Influence propagation: Interest groups and node ranking models", *Physica A: Statistical Mechanics and its Applications,* DOI:10.1016/j.physa.2020.124247.

Bowen Jr., J. T. (2012), "A Spatial Analysis of FedEx and UPS: Hubs, Spokes, and Network Structure", *Journal of Transport Geography,* 24, 419-431.

Burghouwt, G. (2016), *Airline Network Development in Europe and its Implications for Airport Planning,* Routledge, London.

Carrington, P. J., Scott, J. and Wasserman, S. (2005), *Models and methods in social network analysis,* New York: Cambridge University Press.

CAPA (2018), "Long Haul Low Cost Becomes Mainstream as Full Service Airlines Gradually Embrace New Business Models", 2017/06/04.

CAPA (2019), "LCCs: global market share gains led by emerging markets", 2019/02/19.

Chang, V. (2018), "A proposed social network analysis platform for big data analytics", *Technological Forecasting and Social Change,* 130, 57-68, https://doi.org/10.1016/j.techfore.2017.11.002.

Cheung, T. K. Y., Wong, C. W. H. and Zhang, A. (2020), "The Evolution of Aviation Network: Global Airport Connectivity Index 2006–2016", *Transportation Research Part E: Logistics and Transportation Review,* 133, DOI : 10.1016/j.tre.2019.101826

Daft, J. and Albers, S. (2012), "A Profitability Analysis of Low-cost Long-haul Flight Operations", *Journal of Air Transport Management*, 19, 49-54

Dobruszkes, F. (2006), "An analysis of European Low-cost Airlines and Their Networks", *Journal of Transport Geography,* 14(4), 249-264.

Du, W., Zhou, X., Lordan, O., Wang, J., Zhao, C. and Zhu, Y. (2016), "Analysis of the Chinese Airline Network as Multi-layer Networks," *Transportation Research Part E,* 89, 108-116.

Freeman, I. (2004), *The Development of Social Network Analysis: A Study in the Sociology of Science,* Empirical Press, Vancouver.

Hossain, M. M. and Alam S. (2017), "A Complex Network Approach towards Modeling and Analysis of the Australian Airport Network", *Journal of Air Transport Management*, 60, 1-9.

IATA (2018), "Forecast Predicts 8.2 billion Air Travelers in 2037", IATA Press Release No. 62, 2018/10/24.

Jia, T., Qin, K. and Shan J. (2014), "An Exploratory Analysis on the Evolution of the US Airport Network", *Physica A,* 413(1), 266-279.

Jiang, Y., Yao, B., Wang, L., Feng, T. and Kong L. (2017), "Evolution Trends of the Network Structure of Spring Airlines in China: A Temporal and Spatial Analysis", *Journal of Air Transport Management,* 60, 18-30.

Maertens, S. (2009), "Drivers of Long Haul Flight Supply at Secondary Airports in Europe*",* *Journal of Air Transport Management,* 16(5), 239-243.

Moreira, M. E., O'Connell, J. F., and Williams G. (2011), "The Viability of Long-Haul, Low Cost Business Models"*, Journal of Air Transport Studies*, 2(1), 69-91.

Morrell, P. (2007) "Can Long-haul Low-cost Airlines be Successful?", Transportation Economics, 24(1), 61-67.

Renold, M., Kuljanin J., and Kalićć M., (2019), "The Comparison of Financial Performance of Airlines with Different Business Model Operated in Long-Haul Market", *Transportation Research Procedia,* 43, 178–187.

Pels, E. (2008). "Airline network competition: Full-service airlines, low-cost airlines and long-haul markets", *Research in Transportation Economics,* 24(1), 68-74.

Poret, M. D., O'Connell, J. F. and Warnock-Smith, D. (2015), "The Economic Viability of Long-haul Low Cost Operations: Evidence from the Transatlantic Market", *Journal of Air Transport Management,* 42, 272-281.

Prabhakar, N. and Anbarasi, L. J. (2021), "Exploration of the Global Air Transport Network using Social Network Analysis", *Social Network Analysis and Mining*, 11(26), 1-12.

Rodrigo, B. L., Alves, A. F. Mendesm R. J. G. and Cruz, C. P. F. (2021) "Scenarios of the Degree of Centrality and Density of the Networks of the Main Brazilian Airports Between 2003 to 2020", *Revista FSA*, 18(7), 94–109.

Rodríguez, A. M. and O'Connell, J. F. (2017), "Can low-cost long-haul carriers replace Charter airlines in the long-haul market? A European perspective", *Tourism Economics,* 24(1), 64-78.

Saqr, M., Fors, U. and Nouri, J. (2018), "Using social network analysis to understand online Problem-Based Learning and predict performance"*, PLoS ONE,* 13(9), e0203590, https://doi.org/10.1371/journal.pone.0203590

Serrat O. (2017), *Social Network Analysis. In: Knowledge Solutions*, Springer, Singapore.

https://doi.org/10.1007/978-981-10-0983-9_9
Soyk, C., Ringbeck, J. and Spinler, S., (2017), "Long-haul Low Cost Airlines: Characteristics of the Business Model and Sustainability of its Cost Advantages", *Transportation Research Part A: Policy and Practice,* 106, 215-234.
Tabassum, S., Fabiola, S. F., Pereira, F. S. F., Fernandes, S. and Gama, J., (2018), "Social network analysis: An overview", *Data Mining and Knowledge Discovery,* 8(5), e1256, https://doi.org/10.1002/widm.1256.
Valeri, M. and Baggio, R., (2020), "Italian tourism intermediaries: a social network analysis exploration", *Current Issues in Tourism,* https://doi.org/10.1080/13683500.2020.1777950
Wang, J., Mo, H., Wang, F. and F. Jin, (2011), "Exploring the Network Structure and Nodal Centrality of China's Air Transport Network: A Complex Network Approach*", Journal of Transport Geography*, 19, 712-721.
Wasserman, S. and Faust, K. (1994), *Social network analysis: Methods and applications,* Cambridge University Press, Cambridge.
Whyte, R. and Lohmann, G. (2015), "Low-cost Long-haul Carriers: A Hypothetical Analysis of a 'Kangaroo Route'", *Case Studies on Transport Policy*, 3(2), 159-165.
Wittman, M. D. and Swelbar, W. S., (2014), "Capacity Discipline and the Consolidation of Airport Connectivity in the United States", *Journal of Transportation Research Board,* 2449(1), 72-78.
ACI (Airport Council International), https://aci.aero
IATA (International Air Transport Association), http://www.iata.org
ICAO (International Civil Aviation Organization), https://www.icao.int
OAG (Official Airline Guide), http://www.oag.com
WATS (World Air Transport Statistics), https://www.airlines.iata.org
WTTC (World Travel & Tourism Council), http://www.wttc.org