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Robustness of airline route networks

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HIGHLIGHTS

- Air route networks of full-service, low cost and hybrid airlines are examined.
- FSC route networks are built through hub-and-spoke, and LCC through point-to-point.
- Route networks of LCC are more robust than of FSC to isolation of central nodes.
- LCC are also more resilient than LCC against random isolation of nodes.

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ABSTRACT

Airlines shape their route network by defining their routes through supply and demand considerations, paying little attention to network performance indicators, such as network robustness. However, the collapse of an airline network can produce high financial costs for the airline and all its geographical area of influence. The aim of this study is to analyze the topology and robustness of the network route of airlines following Low Cost Carriers (LCCs) and Full Service Carriers (FSCs) business models. Results show that FSC hubs are more central than LCC bases in their route network. As a result, LCC route networks are more robust than FSC networks.

1. Introduction

Air transport is among the most dynamic and toughest competition industries in today's global economy. Liberalization of the airline industry [1] has produced very distinct business models among the airlines [2], with the design of their route networks being a strategic factor, in addition to others such as the cost structure and the ancillaries offered.

Most times airlines make the choice of operating a route based on existing supply and demand volumes, paying little attention to other issues such as the robustness of route network operated by the airline. Network robustness (i.e., network resilience in facing disruptions like node isolation) is considered of secondary importance, although a robust route network can provide great improvement to the stability and security of carrier operations. Many domestic airlines are often associated with the image of a country or region and produce a huge economic impact on their national and international economies. The collapse or a critical error of an airline network can produce high financial costs for the airline and throughout its geographical area of influence [3]. For instance, the eruption of volcano Eyjafallajökull on March 14, 2010 in Iceland restricted European air traffic and left areas out of operation for 30 days [4]. It caused losses of about 10 million USD because of delays in the operating airports.

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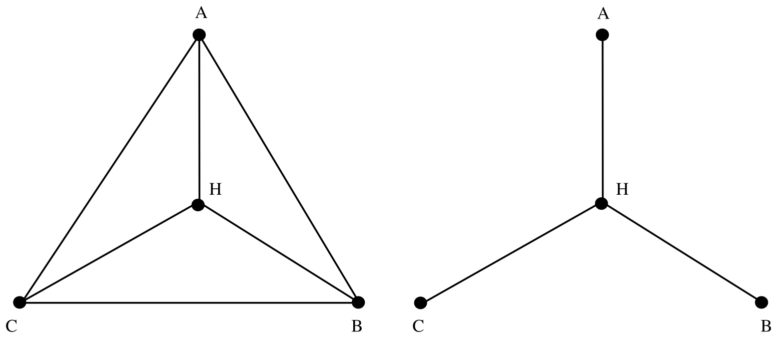

Fig. 1. HS and PP configurations.
Source: [25].

The literature on network robustness makes a distinction between *errors*, the removal or isolation of one or several nodes picked at random, and *attacks*, which consist in the removal or isolation of nodes that play a vital role in maintaining a network's connectivity [5]. The examination of flight networks [6] (i.e., networks where the airports act as nodes and are connected if at least one direct route between them exists) through complex networks techniques can provide a deeper understanding of airline networks' behavior when facing errors and attacks. This analysis can be carried out at different levels of analysis [7]: *global* or *regional*, which take into account all connections of a global or regional network, *alliance*, which considers the routes operated by members of an alliance; and *airline*, where the routes operated by an airline are considered.

Recent articles have analyzed the *topology* of the air transport network (mainly described by the degree distribution) to understand their distribution and characteristics, most of them focused on the global [8] and regional [9–12] levels of analysis. Some studies have optimized the paths of the transportation network [13,14] using techniques such as particle swarm optimization [15,16]. Other studies have analyzed the *robustness* of air transport network in order to determine which airports can be considered critical if they were to cease operations. That stream of research considers the regional [17,18] or global [19] levels of analysis. Finally, Cento [20], Reggiani et al. [21] and Lordan [22] have addressed the study of route networks of individual airlines, and Lordan et al. [23] have analyzed the robustness of airline alliance route networks. But no study, to our knowledge, has attempted to assess the robustness of airline route networks.

The aim of this study is therefore to analyze the robustness of route networks of airlines which are following different business models and facing isolation of nodes picked at random (errors) or the isolation of nodes chosen using a node selection criterion (attacks). In order to compare the robustness of the point-to-point and hub-and-spoke network configurations the set of airlines to be studied will include Full-Service Carriers and Low-Cost Carriers.

2. The influence of airline business models on route network configuration

Currently, there are two predominant business models in the airline industry: *Full-Service Carriers* (FSCs) and *Low-Cost Carriers* (LCCs). These types of carriers are characterized by having, respectively, hub-and-spoke (HS) and point-to-point (PP) network configurations. Both HS and PP configurations can be described schematically through a network of four nodes, as shown in Fig. 1. The HS configuration (right) consists of a central node or hub H connected to the other nodes, thus only three routes are needed to bond the four destinations. In this configuration the central nodes of the route network are determinant to network resilience when facing node isolation [24]. The PP configuration (left) uses a total of 6 routes to connect all possible node pairs. Generalizing these concepts for n airports to connect all their destinations, the PP configuration requires up to $n(n-1)/2$ routes (some of which might not be present if they are not profitable enough) while the basic HS configuration works with only $n-1$ routes [25]. It is also important to consider the temporal distribution of each model, a fact directly related to the schedule of flights for each airline. The hub of the HS configuration causes the concentration of high traffic density in space and time [26].

Arlines' business models and strategies strongly define their network structure. Traditional airline network analysis measures the topology variables depending on traffic distribution or concentration of frequencies [27,28,26]. One objective of these studies is to relate, compare and resemble an airline network to the HS and PP configurations. LCC adopts a PP network configuration because they connect city pairs that offer high load factors and therefore optimize their operability. On the other hand, FSC often develops a HS configuration, offering more destinations by using one or more strategic hubs where large passenger flows concentrate. This allows FSC to get a profitable load factor on routes applying economies of scale [25].

As can be seen in Fig. 1, the HS configuration concentrates a larger volume of flights and passenger traffic in the switching times. For example, to be able to go from B to A and from C to A one must call at H. Therefore, it is necessary to coordinate the arrivals of the first section and the exit of the second at the hub. This would give enough time to operate the connection without hindering the operability of the airline. The PP traffic model is temporally and spatially more dispersed because