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Comparative analysis with a new hub connectivity measure considering revenue and passenger demand

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ABSTRACT

Hub connectivity is an important multi-dimensional performance indicator to evaluate network strategies. This paper develops a new connectivity measure considering customer satisfaction dimensions of detour factor, transfer time, transfer time in relation to flight time, number of destinations, frequency and number of stops, and commercial objectives of passenger revenue and passenger demand. Network performance for six competing hubs are evaluated. Results of the practical scenarios to assess the impact of considering demand and fare on the connectivity competitiveness prove that competitiveness can change significantly depending on the components of the measure. Numerical experiments to evaluate connectivity improvement over the last two years, connectivity based on broadness, destination regions, flight range are described with conclusive results providing improvement directives for each airline. As a different network comparative analysis approach, connectivity of hubs is evaluated based on the selected common sets representing possible target markets that they compete and the results prove that competitiveness is similar to overall results with random sets however it can be different if markets with certain characteristics are selected. The study also compares the new measure and Netscan method, the results of which further support that commercial metrics may change the competitiveness significantly for some airlines.

1. Introduction

Aviation is one of the rising industries with a significant economic impact. In the last 20 years, world air passenger numbers almost tripled and in the next 20 years it is expected to grow more than double (The World Bank, n.d.; (IATA, 2016). Some countries and some regions have more aggressive growth rates compared to world average. Based on Air Transport Aviation Group (ATAG) (2014), aviation industry contributes about $2.73 trillion to GDP through direct, indirect and induced benefits (3.5% of total). By providing rapid travel and increasing connectivity aviation facilitates business and tourism. Simply, connectivity is a measure of the accessibility of the destination of interest from all other destination in the world. Connectivity widens markets, improves efficiency and productivity and encourages investment (IATA, 2007).

As the aviation has been growing, with the change of passenger needs, sector dynamics and the competition, airline business has been obliged to evolve. After the deregulations, hub-and-spoke network model has become a major strategy for airlines to maximize the coverage of their network to get more passenger demand using their resources more efficiently. Airlines with hub-and-spoke system have been competing over not just the point-to-point traffic but over all customers traveling from an origin to a destination which is possible either directly or via a transfer point in the network. With the rise of low cost carriers and the downward trend on the passenger yields cause decrease in the profit margins of the industry and result in fierce competition. Under these trends, network carriers had to make their hubs more efficient and extend their network coverage in order to stay competitive.

Due to the economic and social impact of connectivity for countries and due to the contribution of connectivity of an airline to its competitiveness, performance measures for connectivity have become important for the civil aviation authorities, industry managers and researchers. Connectivity measures are required to evaluate and benchmark the accessibility of countries (and cities) and the network performance of airlines.

The International Civil Aviation Organization (ICAO) in International Civil Aviation Organization (ICAO) (2013) calls connectivity as an indicator of the network's concentration and defines it as “the ability of a network to move a passenger from one point to another with the lowest possible number of connections and without an increase in fare, focusing on, from a commercial perspective, minimum connecting times with maximum facilitation ultimately resulting in benefits to air transport users.”

In the literature, there are different connectivity measures developed and used for empirical comparative analysis for a set of airlines

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and airports. These measures are functions calculating number of connections weighted based on various network properties and parameters such as number of destinations and frequency, transfer times at hub, flight times, number of connections and characteristics of travel paths, etc. Next section details the literature describing these measures. Based on these articles, it is concluded that depending on the connectivity measure and the set of network parameters considered as components of the measure, conclusions of the comparative analysis may change. Also, the set of parameters of interest and the level of their importance may change depending on the party using the measure. Therefore, as a strategic view, while doing a comparative analysis, it is vital to decide which properties of the network have to be taken into account based on the objectives of the experimenter.

This paper proposes a new connectivity measure that also takes commercial objectives, revenue and passenger demand into account in addition to flight times, transfer times, number of destinations, number of frequencies and number of stops. Unit revenue and passenger numbers are included in the measure in order to look from the aspect of an airline manager with a perspective of improving the network in order to produce more passenger revenue. Being located in neighbor regions, operating as major rivals, and having a set of origin and destination pairs with a large intersection set, six airlines' hubs are selected and their network connectivity competitiveness is compared empirically. An extensive computational analysis is done to evaluate competitive position of each network from different perspectives. Sensitivity analysis of the connectivity measure to different parameters and properties is investigated under different practical scenarios that would be used in real life.

The paper is organized as follows. Section 2 overviews the literature describing different connectivity measures. Section 3 presents development of the new connectivity measure. Section 4 describes the implementation details about the function. Section 5 describes the practical scenarios of comparative analysis with results. Section 6 concludes the paper with the final remarks.

2. Literature review

Connectivity measures developed in the literature differ based on the objectives of the interested parties, data availability and network properties. Simply, by definition, connectivity can be calculated based on only the number of destinations or frequencies from the airport of interest. However, as the topic has drawn interest, more properties have started to be included in the connectivity measures, and more extensive and complex methods have been developed. Travel time, flight time, transfer (or connection) time, number of stops, travel distance as proportion of non-stop travel distance (routing factor or detour factor) are some of the common network properties that are used to weight the importance of the destinations.

Jaap deWit (2009) and Airport Council International Europe (2014) describe five connectivity types: direct connectivity, indirect connectivity, onward connectivity, hub connectivity and total connectivity. Direct, indirect and onward connectivity is defined for an airport aiming to measure the accessibility of this airport from/to other points in the network. Direct and indirect connectivity of an airport are measures based on the number of direct flights from/to this airport and the number of indirect flights from/to this airport via a hub airport, respectively. Airport Council International Europe (2014) defines onward connectivity as the indirect connectivity channeled through hub airports, uses hub connectivity for hub airports composing of connections offered between any airports via the hub of interest and describes total airport connectivity as the summation of direct and indirect connectivity. Burghouwt and Redondi (2013) groups connectivity types into two perspectives: accessibility and centrality. Direct and indirect connectivity present accessibility perspective and hub connectivity characterizes centrality.

Burghouwt and Redondi (2009) reviews and classifies connectivity measures in the literature and provides results obtained by the application of these measures for European airports. Network properties and parameters included in each measure are listed and compared in a systematic way. Doganis and Dennis (1989) and Bootsma (1997) propose connectivity measures that qualifies connections based on minimum and maximum connection times. Doganis and Dennis (1989) counts all connections with a connection time that is between 60 min and 90 min. Bootsma (1997) uses 60 min as a minimum connecting time and three different maximum connection times depending on the origin's and the destination's regions (180 min for Europe to Europe, 300 min for Europe to intercontinental destinations and 720 min for connections between intercontinental destinations). Burghouwt and Wit (2005) develops a weighted connectivity measure in which connections are given a quality score based on their connection time and routing factor (fraction of travel distance to the non-stop direct travel distance). They set minimum connecting time to 60 min, maximum connecting time to 180 min for Europe connections and 720 min for intercontinental connections, and maximum routing factor to 1.4 as cut-off conditions. Danesi (2006) proposes a function to measure connectivity considering minimum connection time (set to 60 min), two levels of maximum connection times (120 min for Europe to Europe and 180 min for the remaining), and routing factor.

Budde et al. (2008) develops a methodology using statistically significant pattern concept originally used for behavioural research. Incoming and outgoing flights in a seven day schedule are considered as patterns under some minimum and maximum connection time limits. Malighetti et al. (2008) uses shortest path and quickest way methods to measure hub connectivity. In shortest path version, connections between origin and destination points are counted as qualified if they are one of the connections with minimum number of steps. Similarly, the quickest way counts connections between origin and destination points as qualified if the paths are one of the paths with minimum travel time. Quickest way methodology also considers routing factor and minimum connection time. Veldhuis (1997) presents Netscan connectivity function considering number of direct and indirect connections assigned a quality value based on estimates of perceived travel time and maximum perceived travel time calculated using transfer time, flight time and non-stop direct travel time. Boonekamp and Burghouwt (2017) develops a connectivity measure for air freight based on Netscan methodology. Connections are weighted with some quality factor considering time sensitivity and perishability of goods.

Besides common network parameters such as travel time, flight time, transfer time, detour factor, number of stops, some methods employ other parameters in order to scale the importance of destinations. PWC (2014) lists some connectivity measures from literature based on different network properties: York Aviation Business Connectivity Index weights each destination based on its ranking in the Globalization and World Cities Research Network (GaWC (Globalization and World Cities Research Network, 2016)) that investigates the relationship between cities in terms of globalization; World Bank Air Connectivity Index developed by Arvis and Shepherd (2011) grades routes based on the number of onward connections, in other words, the connectivity of the destinations that are connected to the point of interest are considered; IATA Connectivity Index (IATA, 2007) includes the importance of destinations as weights that are calculated using average number of available seats to destinations and number of passengers at the destination airports in addition to number of flights. Pearce (2007) describes and gives results of a connectivity measure that considers the number of flights, number of seats per flight and the size of the destination airports.

3. Revenue-based hub connectivity function

All the measures in the literature vary depending on the researcher's objective. From the perspective of a government or aviation authority, measures may include some economic and social parameters,