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The opening of direct flights across the Taiwan Strait: the impact on the global role of Taiwan's international airport

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ABSTRACT

Scheduled direct flights between Taiwan and Mainland China were halted for six decades and restarted in December 2008. The Taiwan's government has a policy of developing *Taoyuan International Airport* (TPE), the major international airport in Taiwan, as one of main hubs in East Asia, based on the airport's access to Mainland China. To assess whether the airport is progressing toward meeting the set expectation, this study evaluates the changes in airline networks of the TPE after the opening of direct flights across the Taiwan Strait. The time-dependent earliest arrival time algorithm is applied to global flights in 2004, 2008, and 2012. Empirical evidence demonstrates that providing direct flights across the Taiwan Strait has significantly increased accessibility from TPE to airports in China, but did not improve the centrality of TPE. Additionally, the transfer dependency of TPE on other airports is increasing significantly. This result was based on two major reasons: the first involves the Chinese government's refusal to allow Chinese citizens to use airports in Taiwan as transfer points to and from other countries and the second reflects the competitiveness among airports and airlines in the region. The key finding is that political exclusion of airline use by external governments via travel regulations adversely influences the development of an airport as a global hub.

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1. Introduction

Scheduled direct flights between Taiwan and Mainland China (hereafter the Mainland), which began in 2008, across the Taiwan Strait (hereafter the Strait) are one of the most significant events in Taiwan–China relations in recent decades. Flights between the two countries were stopped in 1949 because of the civil war in China after World War II. Interaction between the two countries was virtually non-existent until November 1987, when Taiwan's central government officially permitted residents of Taiwan to visit relatives and friends on the Mainland. In 1992, the "Act Governing Relations between the People of the Taiwan Area and the Mainland Area," by Taiwan's government, focused on boosting social and economic interactions across the Strait. From 1999 to 2008, travelers from Taiwan to the Mainland (1.9 million to 4.1 millions) and from the Mainland to Taiwan (0.1 million to 0.3 million) doubled and tripled, respectively, within a decade (Mainland Affairs Council, Taiwan, 2014). The massive demand was satisfied by transfer flights through other countries or regions, primarily Hong Kong and Macau. To reduce the unnecessary travel time brought about by the transfer of flights, Taiwan and the Mainland conducted negotiations and opened scheduled direct flights across the Strait (hereafter the Reconnection) in November 2008. As compared with transfer flights, the average amount of time saved by direct flights across the Strait exceeds three hours (Chang et al., 2011).

In addition to decreasing travel time, Taiwan's government is promoting Taoyuan International Airport (TPE), the major international airport in Taiwan, as one of main hubs in East Asia, hoping to exploit the potential in the links created under the Reconnection. This approach was based on two main reasons. First, cross-strait flights account for a significant amount of traffic at TPE. In 2012, TPE provided 40,834 flights to 38 airports on the Mainland; these flights served 6.5 million passengers, accounting for 23% of the total flights at TPE (Civil Aeronautics Administration, Taiwan, 2013). Second was the scale of development in China since Chinese government opened the country's doors in 1979. Based on data from the Bureau of Exit and Entry Administration, China (2014), 411 million travelers crossed the Mainland border in 2011; between 2007 and 2011 the average yearly growth rate was 3.8%. Previous studies have suggested the Reconnection could reinforce TPE's position as an international hub (*e.g.*, Shon et al., 2001; Chang et al., 2011). One can reasonably expect that being

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connected to a blossoming aviation market will elevate an airport's position as hub from either a practical or academic perspective.

Nevertheless, a limited number of studies have empirically examined how the Reconnection has affected the role of TPE. Based on the information gathered to date, one study, by Lau et al. (2012), has been found. Their study analyzed flight data for airports in the Mainland, Hong Kong, and Taiwan between 2007 and 2011, concluding that while the Reconnection has clearly benefited TPE, the airport's status in the Greater China Region has remained unchanged. Their conclusion was based on the regulatory limits on the market and upon direct links among airports. It did not consider indirect connectivity and traffic from global markets. The latter could involve connecting flights via TPE, and perhaps become as important as non-stop flights between two airports. Thus, direct and indirect connections are essential to evaluate an airport's role in a regional network. Furthermore, evaluating a hub using only flights and airports within a limited region can provide a limited view when it has strong links with other regions.

Hence there is a need to re-examine the influence of the Reconnection on TPE's status not only as a provider of direct flights but also due to its function as a global hub. The reminder of this paper is organized as follows. Section 2 introduces the TDEAT algorithm and proposes hypotheses. Section 3 presents study results and Section 4 discusses their implications. Limitations and recommendations for future study are given in Section 5.

2. Research design

This study evaluates airline connectivity between TPE and 150 major airports worldwide using the time-dependent earliest arrival time (TDEAT) algorithm and global flight data for 2004, 2008, and 2012. The TDEAT algorithm, proposed by Miller-Hooks and Patterson (2004), is used to identify the quickest flight-path between two study airports. It can be applied to a hub and spoke system.

In a hub-and-spoke system, a hub airport typically has three attributes: high accessibility, high centrality, and little dependency on other airports. A highly accessible airport is one that makes travelling easy to fly from the airport to other airports via direct or indirect flights, implying that the airport has good service capability and diverse airline networks. If an airport is frequently served as a transfer point, the airport is considered highly central and important to other airports. Conversely, if many of an airport's connections require transfers via other airports, the airport is termed "dependent" and its activity can be easily affected by the operations of other airports. Fig. 1 illustrates these concepts from the viewpoint of airport *A*. The accessibility measure concerns whether *A* is able to connect with other nodes (like *B*) easily; the centrality measure concerns whether *A* is a transfer node for connecting origin–destination nodes (like *B* and *C*); and the dependence measure concerns whether *A* is connected with other nodes (like *D*) via transfer nodes (like *B*). The three attributes can be used to assess an airport's hub-status. According to a review of connectivity measures by Burghouwt and Redondi (2013), accessibility and centrality are two attributes that have been used in connectivity studies of air transportation networks. To the best of our knowledge, an airport's dependency is yet to be utilized.

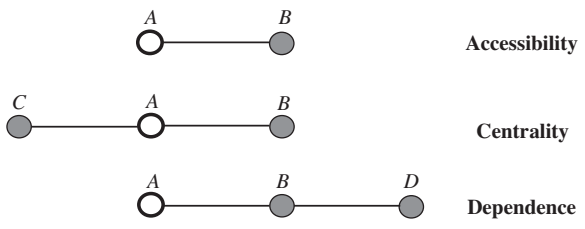

Fig. 1. Concepts of the connectivity attributes.

To apply to this research, one must identify rational paths of a particular pair of *origin–destination* (O–D) airports, and define the three measures of connectivity for an airport.

- *Accessibility of an airport* = the average travel time from an airport to other airports via rational paths.
- *Centrality of an airport* = the percentage of rational paths of O–D airports passing through an airport.
- *Dependency of an airport* = the number of intermediate airports of rational paths from an airport to other airports.

The rational paths of a particular pair of O–D airports are paths that are considerable for rational travelers. Travel time is normally a major concern for a rational traveler. Thus, Malighetti et al. (2008) used the quickest path of an O–D pair to assess network connectivity of airports. Redondi et al. (2011b) extended the work of Malighetti et al. (2008) in considering paths with travel times less than 120% of the shortest travel time to evaluate hub competition. The extended approach seems realistic because it contains alternative flights by considering travel time and travel cost, traveler preferences, seat limitations, and other determinants. Thus, this study defined rational paths as those with travel times within 120% of the shortest travel time.

Searching for the quickest path for a pair of O–D airports is complex because worldwide networks are time-dependent and vary according to flight schedules and flight times. The TDEAT algorithm, which was first applied for air transport analysis by Malighetti et al. (2008), is suitable for this study. The TDEAT algorithm is a part of an algorithm for solving the *time-dependent quickest flow problem* (TDQFP) and was originally developed by Miller-Hooks and Patterson (2004). The TDQFP is applicable to a time-dependent dynamic network, where arc travel times, arc and node capacities, and supply at the origin vary over time. Additionally, this is a decision-making problem of determining paths along which a given supply is sent from a single origin to a single destination and that the last unit of flow arrives at the destination in the smallest amount of time. The TDEAT algorithm is used to find the quickest path among feasible paths in a time-dependent network, where time-dependency is associated with network attributes, such as arc (or flight in this study) connection.

This study adopted the following steps to assemble data for the analysis.

Step 1: Obtain worldwide flight data. To apply the TDEAT algorithm, one must acquire scheduled passenger flight data, including the name of the origin airport, destination airport, and the departure and arrival time for each flight. Because scheduled direct flights across the Strait began at the end of 2008, the newest data gathered when this study was conducted were for 2012. Worldwide flight data for 2004, 2008 (before the Reconnection), and 2012 (after the Reconnection) were obtained from the Innovata LLC. The Innovata LLC maintains and markets flight schedules database drawn from over 900 participating airlines. The database has been widely used in various air transport studies, such as Burghouwt and Redondi (2013), Grubesic et al. (2008, 2009), and Malighetti et al. (2008).

Step 2: Determine the period for analysis. To prevent seasonal variations, this study collected information from the standard off-peak period and considered the weekdays (Monday to Friday) of the second week in November as the period in each year for analysis (2004, 2008, or 2012). Furthermore, the continuous time frame of flight schedules was changed to a discrete one when using the TDEAT algorithm. This study used five minutes as the time unit, such that each day in the period has 288 units. The used time unit

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