Journal of Air Transport Management 52 (2016) 11–22

Contents lists available at ScienceDirect

Journal of Air Transport Management

journal homepage: www.elsevier.com/locate/jairtraman

# Measuring aeronautical service efficiency and commercial service efficiency of East Asia airport companies: An application of Network Data Envelopment Analysis

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ARTICLE INFO

*Article history:*
Received 3 April 2015
Received in revised form
7 October 2015
Accepted 3 December 2015
Available online 29 December 2015

*Keywords:*
Airport company
Efficiency
Controllable factors
Network DEA
Regression analysis

ABSTRACT

Improving operation efficiency has become an important development strategy for many airport companies. However, there is little research on these companies' operating process decomposition or discussing the causes of inefficiency in sub-processes. This study evaluates the overall efficiency and the operational efficiencies of aeronautical service sub-process and commercial service sub-process for 10 East Asia airport companies from 2009 to 2013 using Network Data Envelopment Analysis (NDEA) and identifies the key influencing factors of respective sub-processes efficiency by employing the Panel Data model. The first-stage NDEA results indicate that only Airport Authority Hong Kong in 2012 and 2013 performed efficiently in both sub-processes and achieved overall efficiency. The overall efficiencies of all other companies are not high. During the entire study period, in aeronautical service sub-process, Beijing Capital International Airport Co., Ltd. and Shanghai International Airport Co., Ltd. performed efficiently, while in commercial service sub-process, only Hong Kong airport performed efficiently. The second-stage regression analysis implies the number of airlines served and the number of destinations have significant and positive influences on the efficiency of aeronautical service. Non-aeronautical revenues and service quality have significant and positive influences on commercial service efficiency.



## 1. Introduction

In recent years, the sustainable economic development in East Asia, particularly China's rapid economic advances, has not only promoted the development of the air transport industry in the region, but also has resulted in fierce competition in major airports (Abrate and Erbetta, 2010; Chang et al., 2013; Ha et al., 2013; Tsui et al., 2014). In this scenario, many airport companies have begun to adjust their development strategies, such as expanding airport infrastructure and paying more attention to internal operational management by making full use of existing resources and improving the efficiency of operations. Based on the above mentioned situations, it is very important to measure airport companies' operating efficiency with appropriate evaluation methods and to investigate the factors controlled by the company managers in airport companies.

From a service production perspective, the whole service system in an airport company is classified into two closely related broad categories: aeronautical service and non-aeronautical service. The aeronautical service refers to all essential operational services and traffic-handling services, including aircraft landings and take-offs, passenger service and cargo handling in apron area, ground support services, and fire-fighting services for domestic and foreign airlines. On the other hand, the non-aeronautical business, that is also known as commercial service (Adler and Liebert, 2014; Oum et al., 2003, 2007; Oum and Yu, 2004), usually consists of franchise-based operations and self-operations, such as ground handling agent services supplied for airliners, in-flight catering services, duty free and other retail shops in the terminals, restaurants and other catering businesses in the terminals, leasing of advertising space inside and outside the terminals of the airport, provision of goods warehousing, cargo handling and information processing services in the terminals, car parking services, ground handling facilities for ground handling agent companies, etc. Since there are different airports in different market environments, the service products developed by different airport companies are different. Some companies emphasize the development of the aeronautical services, and pay attention to the construction of a hub in order to improve aeronautical business ability, such as Beijing

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http://dx.doi.org/10.1016/j.jairtraman.2015.12.001
0969-6997/

Capital International Airport Co., Ltd. (BCIA) and Shanghai International Airport Co., Ltd. (SIAC). On the other hand, some companies pay more attention to the development of non-aeronautical services, which innovate service products and improve passenger service experience through exploiting the complementarities between aeronautical services and commercial services for advancing the overall operating performance; for instance, Changi Airport Group (Singapore) Pte., Ltd. (CAGP), Narita International Airport Corporation (NIAC), and Incheon International Airport Corporation (IIAC) (Abrate and Erbetta, 2010; Oum and Yu, 2004).

Based on the above situations, some researchers have begun to pay close attention to exploring the efficiency change of the airports in the Asia–Pacific region, in order to reveal their path of development (Chang et al., 2013; Fan et al., 2014; Fung et al., 2008a; Ha et al., 2013; Lam et al., 2009; Tsui et al., 2014). However, these studies regard an airport company as a black box and analyze the company's operating performance through comparison of input and output of the entire service system of the company. Moreover, fewer studies focused on the decomposition of service processes, evaluated and discussed the efficiency of different service sub-processes. Fewer scholars explored the factors controlled by the company managers as they influence different service sub-processes such as different service products, service objects and service quality. Hence, in order to fill in the gaps left between previous studies, this paper will focus on the following contents: first, the airport company's service system is decomposed into two related sub-processes, namely aeronautical service and commercial service, so as to measure the overall efficiency of the service system and the operating efficiency of each process by applying a relational Network Data Envelopment Analysis (NDEA) (Kao and Hwang, 2008) to a dataset composed of ten airport companies in East Asia observed over a five-year period (from 2009 to 2013). Second, we investigate the impact of the controllable factors on the level of efficiency for two sub-processes using the Panel Data regression model. Meanwhile, this methodological framework enables us to provide new evidence with respect to the debated topics of efficiency in the airport industry. Furthermore, the results may provide effective suggestions for managers and decision makers regarding the improvement of service to increase the operation efficiency of airport companies.

The remainder of the paper is structured as follows. Section 2 presents the literature background in regard to the evaluation of efficiency of airports or airport companies. Section 3 presents a brief introduction to the methodology applied to estimate the efficiency scores of overall and sub-processes for the service system of airport companies, and the impact of the service strategies on the estimated efficiency scores of the two sub-processes. Section 4 describes the dataset, including the input and output variables as well as the influencing variables used in the two-stage analysis. The results are presented and discussed in Section 5, whilst in Section 6 some concluding remarks and suggestions are offered.

## 2. Literature review

In extant studies, there are several methods to measure and evaluate airport or airport company performance including Total Factor Productivity index (TFP), Data Envelopment Analysis (DEA) and Stochastic Frontier Analysis (SFA). In the earlier studies, these methods were applied by Abbott and Wu (2002); Gillen and Lall (1997); Hooper and Hensher (1997); Oum et al. (2003); Parker (1999); Pels et al. (2001); Yoshida and Fujimoto (2004). Following their research, these methods have become widely used methods of investigating airport or airport company efficiency in the world (e.g. Abrate and Erbetta, 2010; Adler et al., 2013; Barros and Sampaio, 2004; Barros, 2008a, 2008b; Gitto and Mancuso, 2012a, 2012b; Malighetti et al., 2007; Merkert et al., 2012; Merkert and Mangia, 2013; Nicola et al., 2013, etc.). Likewise, all of these have been adopted to evaluate the level of efficiency for Asia airports or airport companies, as shown in Table 1.

In these studies, the numbers of passengers, cargo, and aircraft movements were always considered as output variables and the key point of evaluation was the efficiency of airport aeronautical services. Only Oum et al. (2003), Oum and Yu (2004), Oum et al. (2007) and Yu (2004) have added commercial services revenue and airport revenue to output variables and more comprehensively measured the operational efficiency of the airport or airport company. In recent years, Yu (2004), Yu et al. (2008) and Fan et al. (2014) applied both conventional DEA and directional distance function due to simultaneously taking desirable and undesirable outputs into account, such as aircraft noise and delayed movements. However, the input variables were not consistent; one of the reasons may be lack of available data related to the input of airport companies or because it is very difficult to gather the data of concern for each airport company investigated. In the prior studies, the input variables mostly involved three categories such as labor and capital input, along with operations cost. Labor input was denoted by number of employees or price of labor or cost of labor or salary (e.g. Ha et al., 2013; Lam et al., 2009; Li, 2014; Oum et al., 2003, 2007; Oum and Yu, 2004; Tsui et al., 2014; Yoshida and Fujimoto, 2004; Yu et al., 2008). Moreover, capital inputs may be divided into two categories for runway and terminal as shown in Table 1. The input of runway was represented by number of runways or runway length or runway area; similarly, the inputs of terminal were expressed by cargo terminal size, passenger terminal size or total size (Chang et al., 2013; Chow and Fung, 2012; Fung et al., 2008a, 2008b; Ha et al., 2013; Lam et al., 2009; Merkert and Assaf, 2015; Tsui et al., 2014; Yoshida and Fujimoto, 2004; Yu, 2004, etc.). In addition, the operation cost usually was represented as soft cost input, as used by Oum et al. (2003), Oum and Yu (2004), Oum et al. (2007).

Above all, these studies considered an airport company as a whole, such as a black box, by exploring the overall efficiency and productivity change according to the initial inputs and the final outputs. They neglected intermediate products of linking activities in an airport company, or failed to distinguish the sources from different sub-processes resulting in airport company inefficiency (Tone and Tsutsui, 2009; Tsui et al., 2014), which cannot help managers to formulate corresponding improvement strategies. More recently, the Network DEA model was developed to measure airport efficiency, as used by Lozano et al. (2013), Maghbouli et al. (2014), Yu (2010). They divided the airport operation into two sub-processes, including aircraft movement process and aircraft loading movement process and measured the efficiencies of each sub-process, respectively. However, they employed input and output variables that mainly involve aeronautical service rather than non-aeronautical service without considering the influence of commercial service on airport efficiency. Yu (2010) first used employees, runway area, apron area, terminal area as the first-stage input variables and numbers of passengers and movements, along with cargo volumes, as the second-stage output variables; meanwhile, the intermediate outputs/inputs were movements per year and passengers per year. Lozano et al. (2013), Maghbouli et al. (2014) divided the airport operation into two sub-processes and applied the first input variables as total runway area, apron capacity, number of boarding gates, and the final output variables as number of passengers and cargo volumes. But the intermediate outputs/inputs were different, among these Lozano et al. (2013) considered the first-stage outputs to include one desirable output (i.e. aircraft traffic movements) and two undesirable outputs (i.e. number of delayed flights, accumulated flight delays), while the