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Studies for air traffic management R&D in the ASEAN-region context

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We investigated flight delays and found that thunderstorms largely affected the flight delay duration. By performing Monte Carlo simulations, we also examined several scenarios to estimate the airport runway capacity. The results found might allow identifying crucial factors, meeting the rising air transport demand for more years ahead. In addition, a functioning modelling and simulation capability was established by the Air Traffic Management Research Institute to carry out analyses of traffic flows and airspace structures throughout the ASEAN region and to provide solutions for capacity and efficiency enhancements.

1. Introduction

Singapore has built its air links, and grown as a hub, connecting its Southeast Asian hinterland to the world via air transport activities (Chia, 2015). The US has growing financial ties in Southeast Asia (Wang et al., 2011). Studies (Shao and Yang, 2013) found competition between China and Association of Southeast Asian Nations (ASEAN) declined and integration increased. Air transport is a critical element in the flow of capital and people through the Asia Pacific region (Duval, 2008).

A wave of low-cost carriers (LCCs) in ASEAN has raised expectations that the experiences with LCCs in other main markets would be duplicated in this dynamic region (Hooper, 2005). Constructing the regional tourism system (Zhang et al., 2014) would increase the opening up of new routes. How to efficiently enhance the aviation capacity is a vital issue to promote economy growing quickly and sustainably (Zheng et al., 2009).

The ASEAN has decided to form open skies within the ASEAN region, although the member states differ largely regarding their aviation policies, strength and size of the aviation industries, and GDP per capita (Forsyth et al., 2006b). In 2008, the ASEAN member states accepted a Multilateral Agreement on Air Services, which might result in an eventual Single Aviation Market arrangement (Tan, 2010).

Airlines in the ASEAN region were predicted to have delivery of over 3000 aircraft worth about €500 billion by 2032, Boeing forecasted that the passenger movements within and from this dynamic region would increase by 6.5% in the next 20 years, and the EU initiated the ASEAN Air Transport Integration Project in 2012 (Buyck, 2014). Even after the ASEAN Single Aviation Market starts, founding joint ventures may be an approach for foreign carriers to enhance the network in ASEAN (Hanaoka et al., 2014).

With the new open skies policy, it is expected to increase regional and domestic connectivity and thus increase the overall capacity of the region (Forsyth et al., 2006a). With the surge of LCCs, studies have also been conducted on how they might affect the efficiency of airports. Choo and Oum (2013) reported that airports with the increasing number of LCCs actually had decreasing efficiency. Hence, more studies should be conducted to increase the efficiency of air transport operations with increasing LCCs (Tee, 2015).

The runway capacity of an airport (Andreeva-Mori et al., 2013; Gelhausen et al., 2013) is the number of airplane movements that can be safely performed on the runway as approved by the relevant authorities (Tee, 2015; Varun, 2015). It is reflected as the number of departure and arrival flights per hour (ICAO, 2004). The capacity of any airport is also affected by the performance of the airlines at that airport. Jenatabadi and Ismail (2014) presented a structural equation method (SEM) for estimating the performance of the airlines. The same SEM method was utilized by Chiou and Chen (2010) and Yang et al. (2012) with respect to LLCs. Hsu and Liu (2012) and Chang (2012) studied the effects of cabin safety on airport capacity. The effects of traffic control on airport capacity were studied by Kuo et al. (2012). Other methods that have been used to study the factors affecting the capacity of an airport are multiple criteria decision making (Hsu and Liou, 2013), structural equation modeling

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(Jenatabadi and Ismail, 2012), order preference technique (Feng and Wang, 2000), regression (Hung and Liu, 2005; Clougherty and Zhang, 2009), data envelopment analysis (Barbot et al., 2008), time series (Flouris and Swidler, 2004), and ANOVA (Gilbert and Wong, 2003). A mathematical probability (Monte Carlo) method was used by Irvine et al. (2015) to estimate the capacity of the airports in the south of England and London. Their study depicted the results of having new runways at various airports and provided ways of increasing capacity by using existing runways in a different manner. Pitfield and Jerrard (1999) also used the same technique to estimate the capacity of Rome Airport and analyze the concept of unconstrained capacity. The advantages of Monte Carlo simulations are flexibility and simplicity (Sparrow, 2007) via random simulations (Osaki et al., 2008).

There was previously no ASEAN-wide institution that conducted research to enhance capacity and efficiency for the eventual seamless ASEAN airspace from the operator and airspace user's perspectives. Hence, a functioning ASEAN modelling and simulation capability was established by the Air Traffic Management Research Institute (ATMRI), so as to perform analyses of traffic flows and airspace structures throughout the ASEAN region and provide solutions for efficiency and capacity enhancements using simulation and modelling tools. ATMRI researchers were trained by EUROCONTROL in Singapore and EUROCONTROL's Headquarters to be proficient in the use of SAAM (an integrated system developed by EUROCONTROL). The ASEAN simulation and modelling function enables the establishment of the current baseline of traffic demands.

Besides the development projects collaborating with EUROCONTROL and various ASEAN Member States, the RACE (Regional Airspace Capacity Enhancement) program in the ATMRI also undertakes basic research. For example, the future air traffic demands in the ASEAN region were forecasted, considering various factors such as gross domestic products (Phyoe et al., 2016a), population growth (Phyoe et al., 2016b) and high-speed train (Yeo and Zhong, 2016), using various models (Sailauov and Zhong, 2016a; Guo and Zhong, 2017). Visual conspicuity of departing and approaching aircraft was studied by simulations (Xie and Zhong, 2016b). A model to find optimal routes was proposed (Sailauov and Zhong, 2016b), taking account of many factors. An algorithm based on the A* search method was presented (Xie and Zhong, 2016a) to avoid prohibited areas, collision (Chee and Zhong, 2013) and bad weather and to determine the optimal path. The current daily CO_2 and NO_X emissions due to the air traffic in the ASEAN region were investigated (Aneeka and Zhong, 2016). The airspace load (Zhong et al., 2016) and the relationship between sector size and controller workload (Trong et al., 2016) were also studied. Recent advances for more efficient air traffic (Zhong, 2016) and more efficient airspace in this region (Goh and Zhong, 2016; Xie et al., 2016) were explored.

Besides the above research works reported in 2016 and 2017, we also presented two initial research projects at ATRS 2015, which are included in this article in the special issue. We investigated the flight delays in December 2013 as our very-first-step project. A *t*-test and an ANOVA were conducted with two sets of the delays to determine that thunderstorms would largely influence the flight delay duration, and the flight delay caused by bad weather would affect the airport capacity (Lin, 2014; Lee and Zhong, 2016). As our second-step project, we used a fast-time simulator for the first time at that time available in our university, and conducted simulations to quantify and compare the relative capacity enhancements that might be carried out, including an additional runway and possible changes of operating practices. The study examined several scenarios to estimate the airport runway capacity. The results found might allow identifying crucial factors, meeting the rising air transport demand for more years ahead (Varun, 2015).

As one non-review paper cannot cover so many research topics discussed above, the rest of this article is organized as follows. The next section presents briefly the study on flight delays due to thunderstorms. Section 3 details the study for estimation of runway capacity, concentrating on one study (as also suggested by the reviewers of this article). Section 4 summarizes the studies.

2. Flight delays due to thunderstorms

Flight data for December 2013 were collected manually from flightstats.com, and weather data were from the National Environmental Agency.

Hauf et al. (2002) reported that a thunderstorm might have an influence an hour before and after the reported time of the thunderstorm. This means that after a thunderstorm has occurred, the aftermath may cause an unsteady state in the traffic.

To preserve the similarities of the operational environments as much as possible, reference days (being the near days of the weather-interfered-days) were selected from the non-weather-interfered-days. The delay of every flight occurred during a thunderstorm was compared with the average delay of the corresponding reference days. The difference was the weather-induced delay. Then, the total delays were calculated.

From an article (Civil-Aviation-Authority-of-Singapore, 2012), a figure of 430,000 optimal flight movements based on current operating conditions was obtained. This figure was used as a benchmark for the comparison with the actual flight movement condition. Under the optimal condition, the total thunderstorm delay was converted to an optimal number of flight losses. The total thunderstorm-induced delay was converted to the actual number of flight losses. These two numbers could be used to estimate the monetary values of the delays induced.

The hypothesis that thunderstorms induced higher delays than normal operational delays was tested using a *t*-test and ANOVA. Both tests gave the indication that thunderstorms had a significant impact on the aviation delays.

The difference between the delay duration of the flights operated during thunderstorm hours and the same hourly average delay on its corresponding reference days was calculated and denoted by *After-Normal-Delay*. The total *After-Normal-Delays* were calculated to be 113 h and 3 min. This means that thunderstorms induced an additional 113 h of delays on top of the normal operational delays.

The average delay on weather-interfered-days was 20 min and 19 s. Using the same method, a total delay of 3385 h and 10 min was calculated for non-weather-interfered-days, resulting in an average of 13 min and 27 s. All delays on weather-interfered-days and non-weather-interfered-days in December 2013 were calculated to be 3565 h and 15 min. Thunderstorm-induced delays contributed to ~5% of the total delays, close to the values reported in the literature overseas.

The airport studied can deal with an optimal number of 430,000 flight movements a year (Civil-Aviation-Authority-of-Singapore, 2012), with current operational scenarios. The optimal condition is different from the ideal scenario when an airport can always operate with the maximal throughput. The optimal condition might include insignificant delays and fluctuate throughout the operations. This study assumed that 430,000 flight movements were static throughout the year for simplicity. Then, the profit loss due to thunderstorm-induced delays could be estimated.

3. Estimation of runway capacity

In this study, the Monte Carlo method and a fast-time simulation model were utilized for estimating the capacity of the airport