

Research on Aviation Hub from Perspective of Flight Take-off and Landing Waveforms

Xiong Li^{1*}, Xiaoqing Chen²

¹Planning and Design Institute, China Airport Construction Group Corporation, Beijing, 100029, China

²Aviation Industry Development Research Center of China, Beijing, 100029, China

*Corresponding author's e-mail: lixiong_cacc@163.com

Abstract. To build and form a large-scale hub airport with important international and regional influence is an important symbol for China to step into the group of civil aviation powers. An in-depth analysis was performed centering on the core function of hub airports — flight connection. Flight take-off and landing waveforms at typical hub airports in the world were collected, sorted and studied to make a comparison with domestic airports. Finally, the reasons that affect the operation of hub airports were analyzed from six aspects, including geographic location, flight time resources, resident airlines, on-time performance, transfer facilities and process services, and policy guidance.

1. Introduction

In the 13th Five-Year Plan for Civil Aviation Development in China, the Civil Aviation Administration clearly put forward the specific task of constructing a hub airport[1], namely “strive to improve the international hub competitiveness of airports in Beijing, Shanghai and Guangzhou, reinforce the complementary advantages and collaborative development with surrounding airports” and “gradually upgrade the international hub functions of airports in Chengdu, Kunming, Shenzhen, Chongqing, Xi'an, Urumqi and Harbin.” Flight connection is undoubtedly the essence of a hub airport to be built. The core function of a hub airport is to connect different nodes in the aviation network into a complete air route network through the transfer of passengers and cargo.

This article first analyzed the connection rates of the world's large hub airports and their flight take-off and landing waveforms to find out the problems and gaps in China's airports, and then discussed relevant factors that affect the operation of hub airports.

2. Analysis of connection rates of large hub airports

According to U.S. Sabre's statistical analysis of the number of transfer passengers and connection rates at airports worldwide[2], the top 30 airports in the world in 2015 were shown in figure 1. The top 10 hub airports were Atlanta /ATL, Dubai /DXB, Dallas /DFW, Frankfurt /FRA, Chicago O'Hare /ORD, Charlotte/CLT, Istanbul /IST, Paris De Gaulle /CDG, Amsterdam /AMS, and London Heathrow /LHR, of which 5 airports had a connection rate of more than 50%, and the data at ATL and CLT were even greater than 60%.

In stark contrast to the statistics, no airports in mainland China are on the list (only Hong Kong /HKG ranks 14). In 2015, Shanghai Pudong International Airport contributed the highest connection rate (though only 10%) among airports in mainland China, while the figure of Beijing Capital



International Airport was only 8%. In 2017, the connection rate of Pudong Airport exceeded 12%, and other major domestic airports were about 10%.

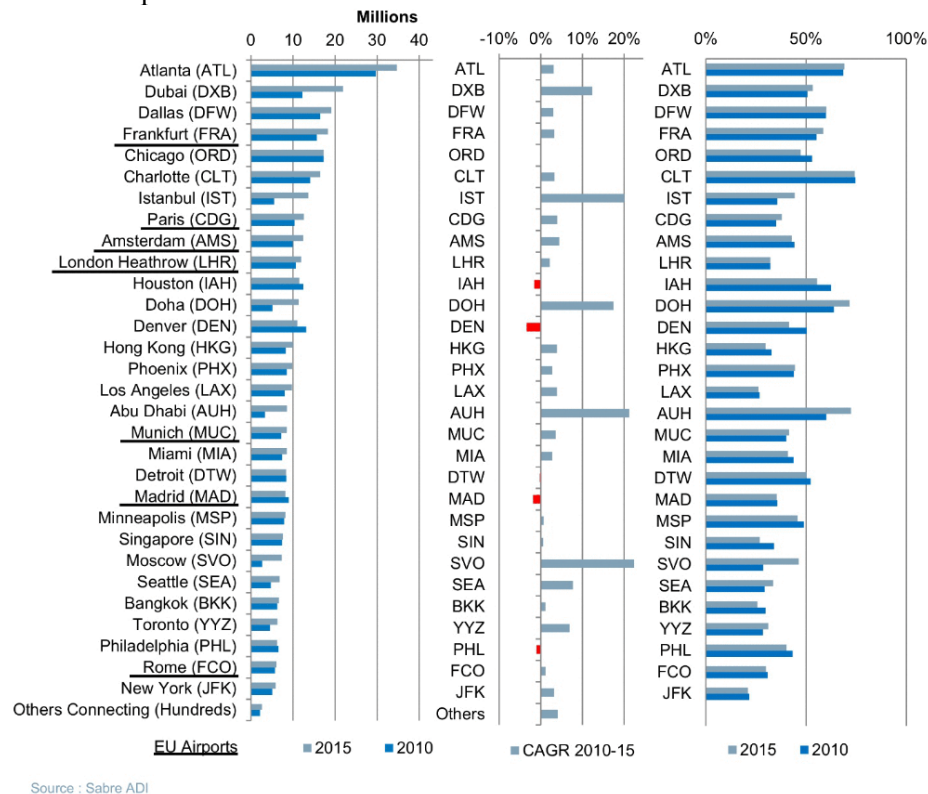


Figure 1. Statistics of connection rates of the world's top 30 hub airports (2010/2015).

Considering from geographic location, the connection rates of airports (Singapore Changi Airport, Incheon International Airport, Narita International Airport) near our country were about 20%, all higher than the 10 major international hub airports (Beijing, Shanghai, Guangzhou, Chengdu, Kunming, Shenzhen, Chongqing, Xi'an, Urumqi and Harbin) that our country strives to build.

3. Characteristics of flight take-off and landing waveforms

For the world's top 50 international mega-airports of annual passenger throughput, this paper applies the flight plan analysis tool of OAG to extract data related to take-off-and-land sorties of daily passenger flight during peak months in 2014 for analysis, and it finally creates take-off-and-land waveform of daily passenger flight[3]. This paper can also draw conclusions about the following four types of representative flight waveforms according to the waveform characteristics of each airport:

3.1. Flight wave with zigzag shape

The flight take-off-and-land peaks appear alternatively. As shown in figure 2, more than three groups of take-off-and-land flight crest (trough) pair are formed in one day[4]. The airport with take-off-and-land flight wave which is zigzag shape usually has distinct characteristics of hub airports. An intensive period of incoming flight is followed by an intensive period of outbound flight. With a close convergence between the incoming flight and outbound flight, it is helpful for the connecting flight to flexibly arrange the take-off-and-land time and improve the transfer efficiency.

3.2. Flight wave with trapezoidal shape

As shown in figure 3, after the flight take-off-and-land sorties per hour reaching the initial peak, the daytime operation period maintains a narrow range of fluctuations until the trough is formed after the take-off-and-land flights are rapidly decreased at night. For the airport with flight wave which is

trapezoidal shape, the take-off-and-land sorties during the operation period are relatively balanced; the overall operational sorties are maintained at a certain level of slight fluctuations; the airport service efficiency is high, which tends to operate at full load. In addition, another objective factor of forming the flight wave which is trapezoidal shape is that environment around the airport is more sensitive to noise, and there is substantial reduction or prohibition of night time flights.

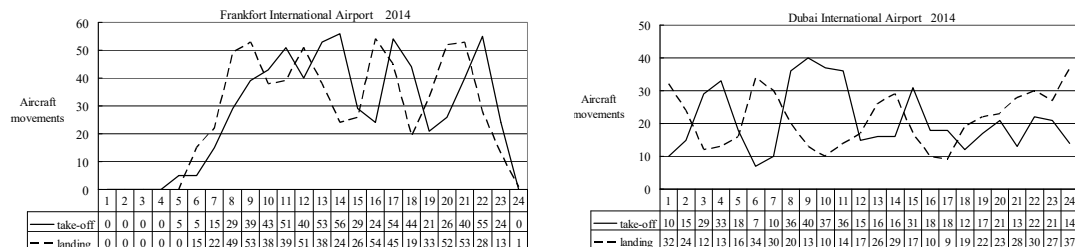


Figure 2. Frankfurt and Dubai International Airport.

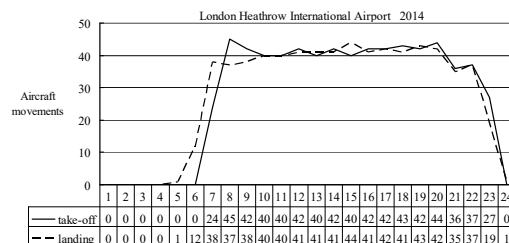


Figure 3. London Heathrow International Airport.

3.3. Flight wave with morning-and-evening-peak shape

The extreme value of take-off-and-land flight wave peak is respectively in the morning and evening. The flight take-off-and-land sorties per hour during the daytime operation period have a certain fluctuation, and the peak and trough appear alternately, as shown in figure 4. The airport with flight wave which is morning-and-evening-peak shape usually has distinct characteristics that set out early and return late, because this kind of airport is usually used as a base airfield of large airline companies with many overnight flights. The usage of airport and runway has a certain imbalance, and the operation pressure of the early departure flight and late incoming flight is great.

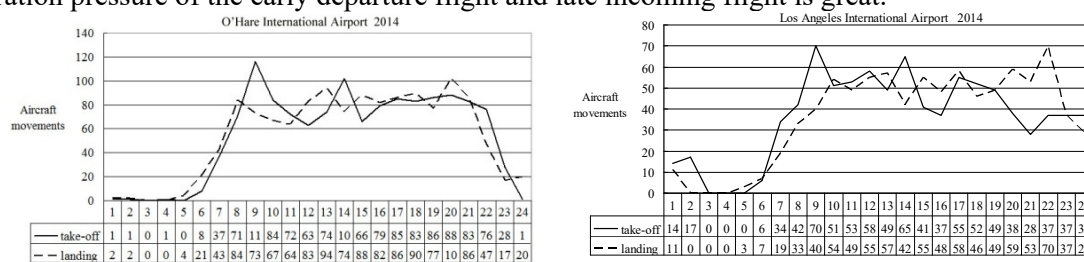


Figure 4. O'Hare and Los Angeles International Airport.

3.4. Flight wave with superimposed shape

As shown in figure 5, the take-off waveform and the landing waveform are similar, the wave peak of take-off and the wave peak of landing are superimposed during some period, and a total of take-off-and-land sorties per hour have significant fluctuations. For the airport with flight wave which is superimposed shape, a total of flight take-off-and-land sorties per hour have strong fluctuations; the daily operation sortie of flight has a relatively large room to improve, which has not yet reached airport's saturating capacity of operation.

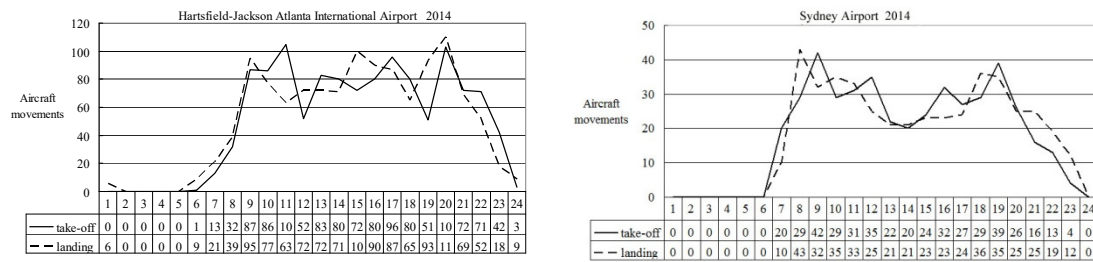


Figure 5. Hartsfield-Jackson Atlanta and Sydney International Airport.

Although these large hub airports showed different waveforms, they still had something in common.

(1) The initial landing peak usually appeared before or at the same time as the take-off peak appeared. The early arrivals usually provide transfer passengers for the subsequent take-offs.

(2) Three pairs of landing-take-off peaks would be formed in one day. That is to say, a landing peak and its adjacent take-off peak formed a landing & take-off peak pair which repeatedly appeared in the waveform of one day, especially in sawtooth waveforms.

(3) Sawtooth flight waves or sawtooth-like flight waves were the most common waveforms at large hub airports such as Amsterdam, Denver, Frankfurt, Rome, Hongkong, Singapore, Inchon and so on.

(4) A larger amplitude in superimposed flight take-off and landing waveforms indicated an airport with a larger capacity and greater development potential, especially seen in superimposed flight waves.

For comparison, the flight waveforms of China's four top airports (Beijing Capital International Airport, Guangzhou Baiyun International Airport, Shanghai Pudong International Airport, and Chengdu Shuangliu International Airport) in passenger throughput were collected for analysis (Other large domestic airports had similar waveforms), as shown in figure 6.

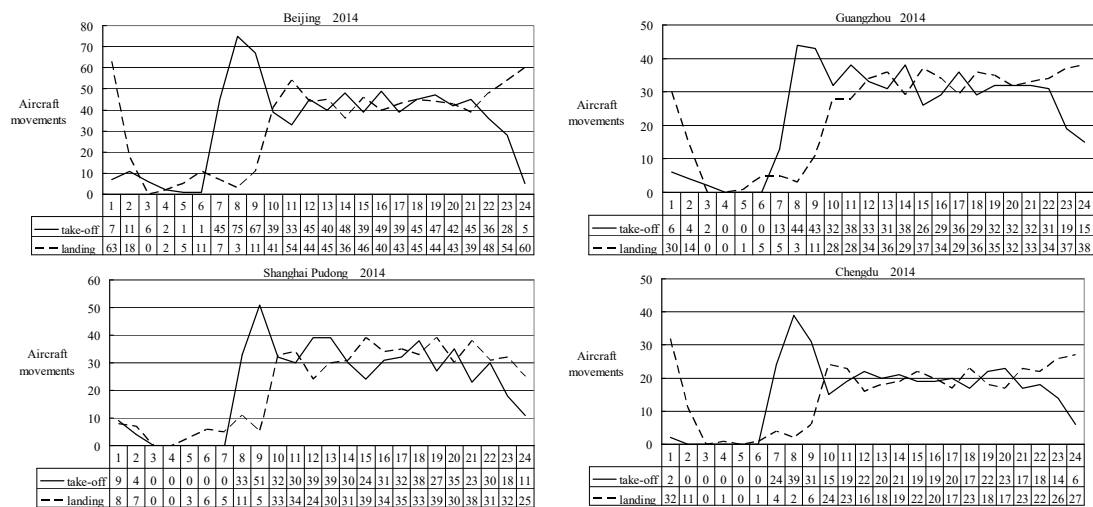


Figure 6. Flight take-off & land waveforms in China's 4 largest international airports.

The flight take-off and landing waveforms of China's large airports basically belong to the category of morning and evening peak flight waves, but the difference with the waveforms of the abovementioned international hubs was mainly that the early departure peak appeared before the landing peak appeared, usually 2~3h in advance and unable to achieve the connection of transfer passengers. Although the take-off and landing peaks in the daytime appeared alternately, the volatility was obviously insufficient and noticeable take-off and landing peak pairs were not formed yet. So there was still a certain gap with the operation mode of international large hub airports.

4. Factors that affected hub operations

The factors constraining the hub operation at large airports are manifold, involving geographic location, regional economy, population composition, route networks, integrated transportation system, base airlines, transfer process, customs policies, service quality and efficiency[5,6], etc., so it is difficult to describe in detail in limited pages. This article started from practice and selected some representative factors for analysis.

4.1. Geographic location

Geographic location is one of the natural attributes of an airport and it cannot be changed. So an airport should select suitable development strategies based on its own characteristics to promote the formation of hub operations. For airports located in state centers (geographic centers, economic centers or population centers, etc.), intercontinental centers or important connecting nodes, it is undoubtedly that they have unique advantageous in building hub airports, such as Hartsfield–Jackson Atlanta International Airport, Dallas/Fort Worth International Airport, Dubai International Airport and Istanbul Atatürk Airport. In terms of our country, Beijing, Shanghai and Guangzhou do not have the abovementioned built-in advantages in the domestic geographic location. Therefore, airports in these places should focus on the development of a domestic-international hub operation mode, while Xi'an, Chengdu and Chongqing are located in the central and western part of China, which is conducive to the formation of a domestic branch - domestic trunk hub operation mode.

4.2. Flight time resources

Flight time resources, especially prime time resources, tend to be saturated at major airports in China. The shortage of flight time resources on the one hand constrains the opening of more international routes at international hub airports, and on the other hand, constrains the addition of more branch routes. The simultaneous development of international trunk lines and small and medium-sized branch lines, though it seems to be contradictory, is precisely conducive to the formation of hub airports. Intercontinental trunk lines, like big rivers, need continuous branches to pour into. Without the support of branches, international routes will suffer low figures in passenger load factor and revenue.

4.3. Resident airlines

The main body of hub airport construction is resident airlines, not the airport itself. In general, hub connection is completed between flights of the same airline or the same airline alliance, to give full play to the advantages of a hub airport through efficient flight connections. Behind the world-famous international aviation hubs, there are always one or more powerful base airlines to support them, such as Delta Air Lines, Inc. and AirTran Airways at Atlanta Airport, Emirates at Dubai Airport, Lufthansa at Frankfurt airport, Singapore Airlines Limited at Singapore airport, etc. In addition, “low-cost” aviation that focuses on the development of branch aviation generally will also promote in the formation of hub airports.

4.4. On-time performance

The on-time performance of an airport is the key to ensure the efficient operation and connection of flights, and it is particularly important for connecting flights. The delay of one flight will not only affect the operation of the follow-up flights, but also affect transfer passengers' behaviors and ideas, and impair their travel experience. In addition, if excessive consideration is given to the occurrence of flight delays, airports will have to leave sufficient transfer time and give unnecessary wait to passengers. These factors will undoubtedly force passengers to give priority to direct flights.

4.5. Transfer facilities and process services

Well-equipped transfer facilities and a convenient transfer process will undoubtedly greatly enhance passengers' transfer experience. On the contrary, it will reduce passengers' willingness to have a connecting flight. Large international hub airports should, by combining the planning of domestic and

international transfer passengers' foot traffic flow in airports, rationally set up an efficient, concise and clearly marked passenger (and checked baggage) transfer process, and fully consider the establishment of transfer lounges, service counters, and other convenient transfer facilities.

4.6. Policy guidance

Policy guidance contains at least two aspects, one is the airport evaluation system and the other is supportive policies.

In terms of the airport evaluation system, at present, three major traditional indicators are still used in China to measure the development speed of an airport, namely passenger throughput, cargo and mail throughput, and aircraft movements, especially passenger throughput. In the context of actively building hub airports, indicators such as passenger connection rate, radiation area and route network may also be considered as standards to evaluate the development of an airport.

Supportive policies refer to the relevant supporting policies that encourage hub operations, such as convenient customs and visa policies, support policies for base airlines, and route network subsidy policies. Such subsidy policies should be regarded as a supplementary means in the initial stage of route opening. Whether the route can work well or not still mainly depends on sufficient passengers and stable route arrangements.

5. Conclusion

Building powerful international and regional hub airports is a hallmark of a civil aviation power, but the path is tortuous and difficult to achieve overnight. In the policy level, the relevant guidance, encouragement and support should be provided. In the airport level, infrastructure construction should be accelerated and more flight time resources should be released; transfer facilities and process services should be arranged scientifically and rationally; and airports should encourage base airlines to develop in different ways from other airlines and thus to achieve mutual benefit and win-win results. In the airline level, the central route network should be rationally designed, and take-off & landing flight pairs based on sawtooth flight waves should be established, to optimize transfer process and improve transfer passengers' travel experience.

Acknowledgments

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