Research on planning and design of airport airfield area

Li Ke*, Shao Bin
Aviation Engineering Institute, Air Force Engineering University, Xi’an 710038, China
*Corresponding author’s e-mail: lkkgd12@163.com

Abstract: Airport status in city construction, regional layout, and transportation systems is analyzed. Influence of operation and management in military-civilian airports is pointed out from the perspective of airport planning and design and operation management. The airfield planning and design are analyzed from the capacity of runway, taxiway, and apron. The displaced threshold can meet the needs of the aviation business, while taking reconstruction and expansion of airport.

1. Introduction
Airport is a complex system engineering and a part of city[1]. Airport planning is an important part of city planning. As a sub-unit of the regional airport group, the airport must be integrated into the overall layout of the national airport construction and closely related to the management and optimization of the airspace. Airport is a comprehensive transportation system and the hub of transportation mode conversion, undertaking the transportation of passengers and cargo. The airport mainly includes airfield area, passenger terminal area, cargo terminal area, complex supporting area, aircraft maintenance area, and other functional areas[2]. The purpose of airport planning and design is to ensure the smooth operation of the airport. The operation and management mode of the airport affects the planning and design of the airport, and the planning and design of the airport and operation management should be combined as a whole.

2. Airport planning and design based on operation and management
The most important function areas of the airport are the airfield area, passenger terminal area and cargo terminal area, which are the core parts of airport. Airport planning is to coordinate the relationship between these functional areas. The operation and management mode of airport directly determines the planning and design of airport facilities. While planning and designing the airport, we must consider the operation and management mode of the airport. This is Liu Wu-jun’s summary on the relationship between planning, design and operation, management of civil transport airport in “airport planning”[3]. Compared with civil airports, military airports or military-civilian airports have relatively few flight sorties and have certain particularity, but the airport planning and design must be studied from the perspective of operation management. The following analysis is carried out by taking the military-civilian airport as an example.

First, the effect of wind on takeoff and landing. According to relevant regulations and standards, the aircraft should not land on the side of the wind or take off and land with the wind. It is better to take off and land against the wind, but the headwind should not be too strong. When determining the direction of the runway, the guarantee rate shall not be less than 95%[1]. When military aircraft flight training and civilian aircraft flight operation are organized in the military-civilian airports, commanders and controllers are usually located in the military tower for flight command and aviation control. When
spring meets summer and autumn meets winter, the wind direction is often changeable. During the flight training of military aircraft, if the wind direction changes, the command tower usually needs to be replaced to realize the requirements of taking off and landing against the wind during the flight interval. Compared with civilian aircrafts, military aircrafts are lighter in mass and more sensitive to wind. Civilian aircrafts may not need to change the direction of takeoff and landing, while military aircrafts have to change the direction of takeoff and landing. In the main landing of the runway, the communication and navigation facilities are more accurate and perfecter, the visual aids are higher, and the airport clearance conditions are well. However, at the secondary landing of the runway, the support facilities are relatively poorer. The temporary change of the command tower increases the risk of flight, to some extent.

Second, while military aircrafts usually take off continuously in batches at a short time, civil aircrafts usually leave or arrive at the airports according to the scheduled time of flight, and have to wait for takeoff or landing. In this case, it is not only necessary to adjust the departure time and approach landing time of the aircraft from the perspective of air traffic control, but also to analyze the taxi route of the aircraft before departure and after arrival, and reasonably plan the layout and configuration of the runway and taxiway of the airfield area. At a military-civilian airport, the crossings of taxi routes between military aircrafts and civil aircrafts reduce the operating efficiency of the airfield and increase the traffic risk on the ground. This situation is shown in Figure 1.

Third, from the viewpoint of common management of military and civil, the airfield area layout is optimized. For example, a parallel taxiway for civilian and military use is set up in front of the military apron. When a civilian aircraft turns to enter the vertical taxiway, its tail jet stream will affect the aircraft parked on the military apron and the staff for maintenance support. At a military-civilian airport, the situation that the road used by military command vehicles and the taxiway used by civilian aircraft are crossing is appeared, which brings great security risks for the operation and management of the airfield area, so airport authority has to send security personnel 24 hours on duty. An airfield layout is shown in Figure 1. From the perspective of planning and safety, it is necessary to make overall planning, comprehensive consideration and multi-use of all kinds of airfield roads, such as parallel roads used by troops, service lanes used by ground vehicles, and common patrol roads, to reduce the crossing of roads and taxiways, to avoid security threats, and to cut investment appropriately.

![Figure 1. An example of airfield layout](image)

### 3. Airfield area planning and design based on airport capacity

Airfield area planning and design is the most important content of airport planning and design, which is directly related to aircrafts and vehicle activities, operation management, and command and support. The capacity of an airport shall take into account the capacity of the airfield area, passenger terminal area, cargo terminal area, and passenger collection and distribution system. Capacity is based on an analysis of demand to meet the needs of the airline business. An important goal of airport capacity analysis is to make the capacity of each system without bottleneck.

Airfield capacity is one of the key factors restricting airport capacity. Airfield capacity is the capacity of serving aircraft sorties of airport facilities, which mainly manifest the capacity of runway, taxiway, and apron. Factors which affect the capacity of the airfield, include airfield geometry, usable airspace, air traffic control procedures, combination of aircraft types, weather conditions, operational command
and support capabilities[4]. The configuration and amount of runways are the key to determine the capacity of airfield. The capacity of the airfield should be built according to the near and long term runway capacity and the demand of gates, according to the principle of "unified planning and phased construction"[4][5].

3.1. Runway capacity
The number of runways almost doubles the capacity of runways, and the corresponding taxiway system is also needed. For example, one runway and one taxiway can handle 10 million passengers a year. When passenger throughput reaches 20 million, one runway is strained and two parallel taxiways are needed. More than 30 million people will need to build two runways. More than 40 million people need three runways[3]. The runway capacity of general airports is shown in Table 1.

| Serial number | Facilities                  | Capacity (person-times/year) |
|---------------|-----------------------------|------------------------------|
| 1             | 1-R/W, 1-A/T/W              | 1000,000                     |
| 2             | 1-R/W, 1-T/W, 1-A/T/W       | 2000,000                     |
| 3             | 2-R/W (Closely-spaced Parallel Runway), 2/3-T/W, 1-A/T/W | 3000,000-4000,000           |
| 4             | 2-R/W, 2-T/W, 1/2-A/T/W     | 4000,000                     |
| 5             | 2-R/W, 4-T/W, ?-A/T/W       | 4000,000-6000,000           |
| 6             | 3-R/W(Closely-spaced Parallel Runway), 3-T/W, 2-A/T/W | 5000,000-6000,000           |

Note: 1. The above is the ultimate capacity of the runway, without considering the influence of other factors;
2. A/T/W is is short for Apron Taxi Way;
3. ? indicates that the number is uncertain.

Runway spacing also has a significant impact on runway capacity. The two runways are too close to be used independently. One must land and the other must take off. If the distance between the two runways is increased to 1035 meters, the two runways can operate independently[2].

3.2. Capacity of taxiway system
In taxiway system, the rapid exit taxiway has a great influence on the increase of runway capacity. The rapid exit taxiway is usually at an Angle of 30 degrees away from the runway. The aircraft can leave the runway at a higher speed because the second aircraft can only use the runway after the previous one has left the runway.

In a complex multi-runway airport, taxiways cross the runway, affecting the take-off or landing of other aircraft and reducing the efficiency of the runway. There is a kind of practice, construction of end-around taxiway at both ends of the runway, using natural terrain at the same time, considering the airport clearance requirements, shortening the distance of slide around. The landing aircraft enter the end-around taxiway through rapid exit taxiway and parallel taxiway, to slide into airport parking space, to avoid the aircrafts crossing the runway, to increase the service efficiency of the runway[6][7].

3.3. Apron capacity
Aprons of military and civil are facilities for parking planes, which function like parking lots for vehicles. In planning military airport airfield capacity, consider the plane from sliding in and out, quick deployment and so on, according to the plane dimension for the classification, in a park a variety of models is the sum of the number of aircraft targets, such as the apron size, turning radius, safe distance as constraint conditions, the use of mathematical software or simulation, get the best in aircraft parking way and could park the largest number of the plane.
4. Displaced threshold When the conditions limited

The displaced threshold of the runway refers to the runway entrance not located at the end of the runway[8]. In some airports, after the expansion of the airfield area, the displaced threshold of the runway has been permanently adopted. The main reasons are as follows: with the increase of the mass of civil aircraft, the aircraft must have a relatively long runway to meet the requirements of take-off speed. When the aircraft is landing, the landing mass decreases, and the resistance can be increased by opening and increasing the wind resistance device and engine counter-injection. The length of landing runway does not need to reach the length of take-off runway. The displaced threshold of the runway reduces the length of the landing runway. The aircraft starts accelerating at the end of the runway during take-off until the take-off leaves the runway. Displaced thresholds of Hong-qiao airport are shown in Figure 3. The permanent displaced threshold of the runway has the following advantages.

4.1. Reduce land requisition

With the construction and development of the city, housing construction and municipal infrastructure around the airport are also gradually improved, land resources and clearance resources are increasingly scarce, and land acquisition and demolition are increasingly difficult. It can be roughly estimated that if the runway of a single runway is extended 300 meters to one end, the land needs to be expropriated about 113,000 square meters. With the extension of the runway, the limit area of the airport obstacles expands and the number of obstacles to be dealt with increases. However, in the case of permanent inward movement of the runway entrance, when the runway is extended by 300 meters, only a small amount of land acquisition is needed, only additional obstacles in the restricted surface of the take-off
runway obstacle are needed, and the approach and landing situation is not considered.

### 4.2. Reduce investment

The entry of the runway has been moved inward, and there are relatively few facilities to be renovated. It is mainly reflected in the following two aspects: navigation facilities, visual navigation AIDS. After the extension of the runway, when the runway entrance is set at the end of the new runway, omnidirectional beacon station, glide platform, rangefinder, beacon beacon station and other navigation stations should be rebuilt according to the construction requirements of the communication navigation station to meet the needs of aircraft navigation and the extension of the runway. With the extension of the runway, the original navigation AIDS cannot meet the requirements of aircraft approach and landing after the extension of the runway, so the approach AIDS lighting system must be reformed. If the runway entrance is moved inward, the navigation light system of the original runway can be modified to meet the use needs of the aircraft, and fewer facilities need to be built.

### 4.3. Avoid the expansion of the noise to some extent

Airport noise has been affecting the lives of the surrounding residents. With the increase of residents' awareness of environmental protection, people's requirements on the environment are getting higher and higher. Many airports are closed at a certain time during the night. After the runway is extended, if the plane lands at the end of the new runway, the flight path of the plane will change accordingly, and the influence area of noise will expand to some extent, which will affect more residents. If the runway entrance is moved inward, as the number of flights taking off and landing at the airport increases, the area affected by noise basically does not expand[9].

### 5. Conclusion

Based on the analysis of the airport operation management and the capacity of the airfield area, some suggestions on the planning and design of the airfield area are put forward. In view of the contradictions existing in the operation of military-civilian airports, solutions are put forward. Aiming at the problem of airfield capacity, the capacity of each part must be studied systematically. The key to solving the capacity problem is to make every part without "bottlenecks". Combined with the actual situation, the method of permanent displaced threshold of the runway is given, which is beneficial to solving the problem of land requisition, reducing investment and controlling noise, so as to meet the needs of airport reconstruction and expansion.

### Acknowledgments

I want to thank Professor Shao Bin for his careful revision of this paper, who helped me point out many mistakes.

### Reference

[1] CAI Liang-cai (2018). Airport planning and design. National Defense Industry Press.
[2] Code for master planning of civil airport (MH-2002). Civil Aviation Administration of China.
[3] LIU Wu-jun (2013). Airport planning. Shanghai Science and Technology Press.
[4] Technical specification for airport hourly capacity assessment (AP-93-TM-2017-01) [S]. Civil Aviation Administration of China.
[5] Aerodrome technical standards (MH5001-2013). Civil Aviation Administration of China.
[6] WANG Wei, LI Long (2016). Study on Operation Strategy of End-around Taxiway and Its Application. Journal of Highway and Transportation Research and Development, 33(6):119-122.
[7] XU Ting, HU Ming-hua, ZHAO Zheng(2015). Analysis of End-around Taxiway's Operational Benefits. Aeronautical Computing Technique, 45(4):112-115.
[8] CHEN Li (2017). Formulation of construction standard scheme of civil airport airfield reconstruction and expansion project without stopping navigation. Standardization in
China,07:136-137.

[9] ZENG Qing-hua, XU Zhi-sheng (2017). Study on Airport Site and Runway Layout Optimization to Reduce Aircraft Noise Impact. Environmental Impact Assessment, 39(6):32-33.