Industrial Engineering and Innovation Management (2022)
Clausius Scientific Press, Canada

DOI: 10.23977/ieim.2022.050307
ISSN 2522-6924 Vol. 5 Num. 3

Airport Terminal Capacity Analysis based on Passenger Transportation Business

Zhihao Chen[1,a], Ruiwen Yu[1,b], Xiaolin Peng[1,c], Qian Wu[2,d,*], Zhifeng Lin[2,e], Duo Wang[3,f]

[1]Operation Control Center, Guangzhou Baiyun International Airport Co., Ltd., Guangzhou, China
[2]Department of Aviation Safety Management, Civil Aviation Management Institute of China Beijing, Beijing, China
[3]Shenzhen Resil-safe Consulting Co., Shenzhen, China
[a]chenzhihao@gdairport.com, [b]yuruiwen@gdairport.com, [c]pengxiaolin@gdairport.com, [d]wuqian@camic.cn, [e]linzhifeng@camic.cn, [f]prepkids@163.com
*****Corresponding author*

Keywords: capacity analysis, airport terminal, domestic flight transportation, business continuity

***Abstract*:** Business capacity is an important content of business continuity management research. This paper constructs an analysis model to study activity process capacity and business capacity, and uses domestic flight passenger transportation business data from the T1 and T2 terminals of A Airport to conduct an empirical study on passenger transportation business capacity. The research results show that passenger transportation business capacity is restricted by its each activity process capacity. Passenger transportation business capacity analysis can be obtained in three steps. First, sort out the activity process of passenger transportation business and determine the sequence of each activity process; then determine the standard capacity per unit time of each activity process; and finally build an analysis model based on the queuing theory. The empirical analysis of A airport shows that the activity process hindering the increase in the domestic flight passenger transportation business capacity of A airport terminals is passengers' luggage check and passengers security check. In an emergency that only T1 terminal handles domestic flight passenger transportation business, T1 terminal can not undertake all domestic flight passenger transportation business of the two terminals even if all resources are available. At this scenario, the passengers' luggage check activity process is the blocking point.

1. Introduction

With the continuous growth of domestic and international passenger transportation, the business pressure on airport terminals is increasing day by day. The occurrence of emergencies such as natural disasters, power failures, equipment failures, etc. has caused the interruption of airport terminal business, which result in a large number of passengers strand in the airport terminal from

time to time. It can be seen that strengthening airport business continuity management and improving emergency response capabilities for handling emergencies are important research topics for airports at present. In order to enhance the business continuity management of various departments of the civil aviation industry, the Civil Aviation Administration of China has issued IB-GO-2016-001 "Business Continuity Management (Emergency Management Practical Tool)" to guide airports, airlines and other departments to establish and improve the business continuity management mechanism. Improving business capacity and sorting out the vulnerabilities of business activities is an important part of business continuity management. This paper will take the passenger transportation business of the airport terminal as an example to study the business capacity problem in depth, and try to answer the following questions: (1) How to find the weak part of the business? (2) How to judge the effectiveness of alternative response measures of the airport terminal after an emergency occurs?

Existing studies have conducted discussions on business capacity and business continuity management. Shi, Zhou and Yu [1] used computer simulation technology Service Model to simulate and analyze the flow conditions of airport terminal passengers check-in, passengers security check, and passengers waiting at different time periods. Based on passengers analysis, Ran and Wang [2] focused on the problem of passengers luggage flow in the airport terminal under the condition that all resources are normal. The research on business continuity management is more about the definition of business continuity management and how to build a business continuity management model [3-5]. The application of business continuity management is more in the financial industry [6-8], the power industry [9] and so on.

In general, the existing research has the following shortcomings: (1) The research on the business capacity of the airport terminal pays more attention to the actual flow of passengers or luggage in different time periods, rather than studies the business capacity of the terminal. Only by understanding the business capacity of the airport terminal and clarifying the upper limit of terminal business can we better respond to actual business operations. (2) The business continuity management in the existing research is rarely applied to the civil aviation industry, but in fact the civil aviation industry has high requirements for business continuity. Thus, this paper will conduct research from the perspective of business continuity management, study the business capacity of the airport terminal by building an analysis model, and analyze the business operation of the airport terminal in emergency based on the results of the business capacity analysis.

2. Methodology

This paper takes the domestic flight passengers' arrival and departure transportation business (hereinafter referred to as the domestic flight passenger transportation business) as an example to show the analysis process of airport terminal business capacity. The process of analyzing the domestic flight passenger transportation business capacity of the airport terminal can be divided into three steps: (1) Sorting out the activity process of the domestic flight passenger transportation business. (2) Determine the standard capacity per unit time of each activity process of the domestic flight passenger transportation business. (3) According to the sequence of the business activity process, the queuing theory is used to construct an analysis equation model.

2.1 The Activiy Process of The Business

This paper takes the domestic flight passenger transportation business as an example to show the process of analyzing the business capacity of the airport terminal. The capacity of an important business is closely related to the capacity of each activity process of the business. Therefore, the first step of the domestic flight passenger transportation business capacity analysis is to sort out the

various activity processes of the domestic flight passenger transportation business in sequence. The activity process of the domestic flight passenger transportation business is shown in Fig. 1.

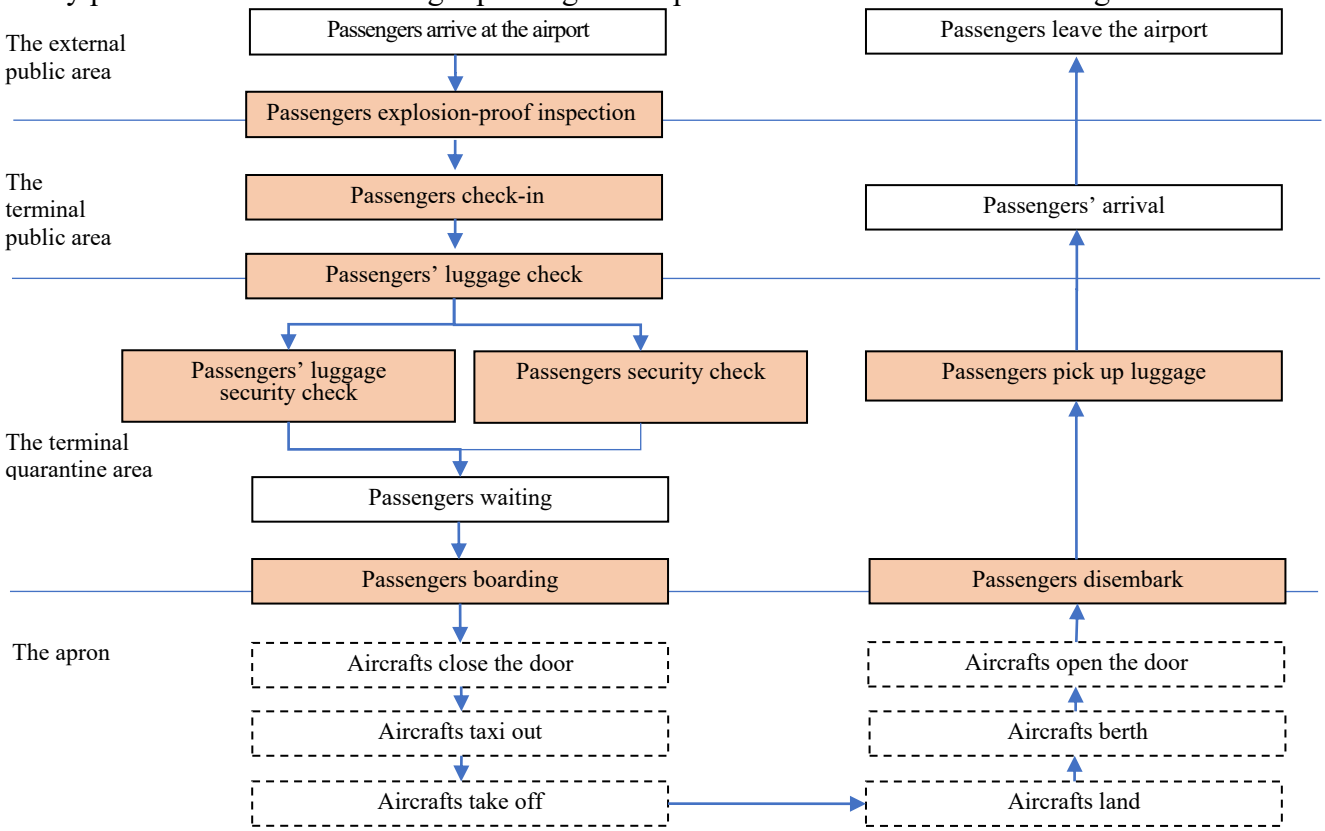

Fig. 1. The activity process of the domestic flight passenger transportation business

This paper only considers domestic direct flights. The solid line boxes in Fig. 1 are the activity processes directly related to passengers. The orange solid line boxes are the key activity processes of the domestic flight passenger business. The dotted line boxes are the activity processes that are not directly related to the passenger. Fig. 1 divides the airport area involved in the domestic flight passenger transportation business into the external public area, the terminal public area, the terminal quarantine area and the apron.

2.2 The Standard Capacity per Unit Time of the Activity Process

The standard capacity per unit time of each activity process is a key indicator for analyzing the activity process capacity and the business capacity. Through normative document research, literature research, visits and surveys, field observations and other methods, this paper gives the standard capacity per unit time of key activity processes in the domestic flight passenger transportation business, as shown in Table 1. Table 1 shows the standard capacity per unit time of key activity processes under normal conditions, and also gives the standard capacity per unit time of the key activity process under the condition of completely manual handling.

2.3 Equation Model

This paper builds an analysis equation model based on the queuing theory. Set P_n as an activity process in the domestic flight passenger transportation business, and set $C(P_n)$ as the activity process capacity per unit time, $n=1,2,3,...,m$. The calculation equation of $C(P_n)$ is shown in (1), where $SC(P_n)$ is the standard capacity per unit time of the activity process P_n, shown in Table 1; $R(P_n)$ is the

resources that the airport terminal can provide for the activity process P_n.

Table 1: The Standard Capacity of the Domestic Flight Passenger Transportation Businiess Activity Processes

Activity Process	Standard Capacity per Hour	Data Source
Passengers explosion-proof inspection	1800 passengers/hour/entrance	Authors' observation [a]
Manual passengers check-in counter	40 passengers/hour /counter	Shi, Zhou and Yu [1], Ran and Wang[2]
Self-service passengers check-in equipment	40 passengers/hour/counter	Shi, Zhou and Yu [1], Ran and Wang[2]
Manual passengers check-in	10 passengers/hour /staff	Flight service statistics
Manual passengers' luggage check counter	20 pieces//hour /counter	Authors' observation
Self-service passengers' luggage check equipment	20 pieces//hour /equipment	Authors' observation
Manual passengers' luggage check	10 pieces//hour /staff	Authors' observation
Passengers' luggage security check equipment	180 pieces//hour /equipment	Security check statistics
Manual passengers' luggage security check	6 pieces//hour /staff	Security check statistics
Passengers security check	140-160 passengers/hour/equipment	Security check statistics
Manual passengers security check	12 passengers/hour/staff	Regulatory requirements and security check statistics
Luggage carousel	4 flight/hour	Authors' observation

[a] Authors' observation of A airport.

$$C(P_n) = SC(P_n) \times R(P_n) \quad (1)$$

Set $AC_{T_i}(P_n)$ as the number of passengers (or passengers' luggage) actually need to be served in the activity process P_n in a certain unit time period (T_{i-1}, T_i), $i=1,2,...24$. Set $QC_{T_i}(P_n)$ as the difference between the number of passengers (or passengers' luggage) actually need to be served in the activity process P_n in a certain unit time period and the activity process capacity in the unit time period, which is calculated by (2). By (2), it can be judged whether each activity process of the domestic flight passenger transportation business in a certain unit time period can provide sufficient services for passengers (or passengers' luggage). If $QC_{T_i}(P_n)$ is greater than or equal to 0, the activity process P_n of the domestic flight passenger transportation business can provide sufficient services for passengers (or passengers' luggage); if $QC_{T_i}(P_n)$ is less than 0, the activity process P_n of the domestic flight passenger transportation business can not provide adequate services for passengers (or passengers' luggage) and need to improve the capacity of the activity process P_n as soon as possible.

$$QC_{T_i}(P_n) = C(P_n) - AC_{T_i}(P_n) \quad (2)$$

3. Empirical Analysis

Take the T1 and T2 terminals of A airport as an example to analyze the domestic flight passenger transportation business capacity and the activity process capacity of the domestic flight passenger transportation business. A airport is a 4F class airport with two runways. A airport has two terminals, T1 terminal and T2 terminal, and the two terminals are connected to each other. In 2019, the annual passenger throughput of A airport exceeded 73 million, with nearly 500000 flights taking off and landing. This section will empirically analyze the domestic flight passenger transportation business capacity based on the T1 and T2 terminals of A airport. At the same time, considering that it is possible to keep only a single terminal to operate in an emergency, this section will further analyze the operation of the domestic flight passenger transportation business when only a single terminal is required to be maintained in an emergency.

According to the above methodology, combined with the current status of various resources of A Airport, the key activity process capacity under the condition that all resources are available, as well as the key activity process capacity of manual operation are measured. As shown in Table 2 and Table 3.

Table 2: The Key Activity Process Capacity of the Domestic Flight Passenger Transportation Business of T1 Terminal

Activity Process Capacity	**Normal Situation (All resources are available)**	**Emergency (Manual operation)**
Passengers explosion-proof inspection	1800*entrance number =28800 passengers/hour	n/a
Passengers check-in	40*manual passengers check-in counter number+40* self-service passengers check-in equipment number =5120 passengers/hour	10* Manual passengers check-in staff number =600 passengers/hour
Passengers' luggage check	20* manual passengers' luggage check counter number+20* Self-service passengers' luggage check equipment number=1680 pieces/hour	10* manual passengers' luggage check staff number=600 pieces/hour
Passengers' luggage security check	180* passengers' luggage security check equipment number=3600 pieces/hour	6* manual passengers' luggage security check staff number=1716 pieces/hour
Passengers security check	140-160*passenger security check equipment number=3500-4000 passengers/hour	12* manual passengers security check staff number= 300 passengers/hour
Passenger boarding	Restricted to the number of terminal boarding gates	
Pick up passengers' luggage	4* luggage carousel number=80 flights/hour	Restricted to the site size

Analyzing the domestic flight passenger transportation business capacity of T1 and T2 terminals of A airport, the following findings are get:

(1) Passengers explosion-proof inspection activity processes at T1 and T2 terminal are non-blocking activity processes. The entrance and staff are sufficient. The possible risk is that the explosion detector equipment is unavailable due to power outages and other reasons. Therefore, in this case, it is necessary to consider the alternative operation such as manual operation or to consider the possibility of canceling the activity.

(2) The domestic passengers' luggage check activity process at T1 terminal is a obviously potential congestion point. There are 84 domestic luggage check counters in T1 terminal. Each luggage check costs about 3 minutes, 1680 pieces of luggage can be handled per hour, which is far less than the average hourly luggage check at A airport (3198 pieces, from the author's field survey).

(3) The key activity process that hinders the improvement of the domestic flight passenger transportation business capacity in the T1 and T2 terminals is passenger luggage check. Therefore, these two terminals should increase passenger luggage check counters, self-service equipment and personnel, which can improve the capacity of passenger luggage check and can finally improve the domestic flight passenger transportation business capacity.

(4) The passenger security check at the T1 and T2 terminals is also a potential congestion point. It is necessary to increase security check channels and security check personnel to improve passengers security check capacity.

Table 3: The Key Activity Process Capacity of the Domestic Flight Passenger Transportation Business of T2 Terminal

Activity Process Capacity	**Normal Situation (All resources are available)**	**Emergency (Manual operation)**
Passengers explosion-proof inspection	1800*entrance number =14400 passengers/hour	n/a
Passengers check-in	40*manual passengers check-in counter number+40* self-service passengers check-in equipment number =7360 passengers/hour	10* Manual passengers check-in staff number= 1190 passengers/hour
Passengers' luggage check	20* manual passengers' luggage check counternumber+20* Self-service passengers' luggage check equipment number =3580 pieces/hour	10* manual passengers' luggage check staff number=1190 pieces/hour
Passengers' luggage security check	180* passengers' luggage security check equipment number=7200 pieces/hour	6* manual passengers' luggage security check staff number=1716 pieces/hour
Passengers security check	140-160*passenger security check equipment number=4760-5440 passengers/hour	12* manual passengers security check staff number=408 passengers/hour
Passengers boarding	Restricted to the number of terminal boarding gates	
Pick up passengers' luggage	4* luggage carousel number=96 flights/hour	Restricted to the site size

Further consider when an emergency occurs, A airport needs to shut down one terminal and only keep the other terminal for operation. This paper analyzes the following scenario: shutting down T2 terminal and transferring all the domestic flight passenger transportation business of T2 terminal to T1 terminal. The results are shown in Table 4. According to the data provided by A airport, the average hourly number of domestic flight passengers departing from T1 is 1929, and the average

hourly number of domestic flight passengers arriving at T1 is 1878. The average hourly number of domestic flight passengers departing from T2 is 1846, and the average hourly number of domestic flight passengers arriving at T2 is 1837.

Table 4: Transfer the Domestic Flight Passenger Transportation Business of T2 Terminal to T1 Terminal

Activity Process	**Normal Situation (All resources of T1 Terminal are available)**	
	Domestic flight passenger departure business	***Domestic flight passenger arrival business***
Passengers explosion-proof inspection	5068 passengers/hour < 28800 passengers/hour [a]	n/a
Passengers check-in	3775 passengers/hour < 5120 passengers/hour	n/a
Passengers' luggage check (or pick up)	3198 pieces/hour >1680 pieces/hour	34 flights/hour <80 flights/hour
Passengers' luggage security check	2500 pieces/hour <3600 pieces/hour	n/a
Passengers security check	3775 passengers/hour <4000 passengers/hour	n/a
Passengers boarding	34 flights/hour <95 boarding gates	34 flights/hour <45 boarding gates
Activity Process	**Emergency (Manual operation)**	
	Domestic flight passenger departure business	***Domestic flight passenger arrival business***
Passengers explosion-proof inspection	n/a	n/a
Passengers check-in	3775 passengers/hour >600 passengers/hour	n/a
Passengers' luggage check (or pick up)	3198 pieces/hour >600 pieces/hour	n/a
Passengers' luggage security check	2500 pieces/hour >1716 pieces/hour	n/a
Passengers security check	3775 passengers/hour >300 passengers/hour	n/a
Passengers boarding	34 flights/hour <95 boarding gates	34 flights/hour <45 boarding gates

a. The first figure is the number of passengers (or luggage) need to be handled per hour, and the second figure is the activity process capacity shown in Table 2.

Based on the results in Table 4, we have the following findings:

(1) The overall design capacity of T1 terminal is smaller than that of T2 terminal. If the passenger transportation business of the two terminals is concentrated in T1 terminal, the operation efficiency of T1 terminal will decrease sharply, especially in manual operation situation.

(2) When all resources of T1 terminal are available, T1 terminal can not take the domestic flight passenger transportation business of its own and T2 terminal. The luggage check activity process is an obvious blockage. The number of luggage need to be checked is 3198 pieces per hour, but T1

terminal can only handle 1680 pieces. In other words, if A airport can improve the activity process capacity of luggage check, then T1 terminal can undertake all domestic flight passenger business of A airport in an emergency. Besides, The number of passenger need to have security check is 3775 per hour, which is very close to the passenger security check capacity (4000 passengers/hour) and means security channels may be very crowded at this scenario.

(3) When all activity processes of the passenger transportation business need to be operated manually, T1 terminal can not take domestic flight passenger business of its own and T2 terminal. At this situation, the four activity processes, passengers check-in, passengers' luggage check, passengers' luggage security check, and passengers security check, are all blocking points, and the operation efficiency of T1 terminal is greatly reduced.

4. Conclusion

Business continuity management is an important subject and practical tool for airport management now and in the future, and business capacity is an important content of business continuity management research. This paper constructs an analysis model to study activity process capacity and business capacity, uses passenger transportation business data from the two terminals of A airport to conduct an empirical study on passenger transportation business capacity, and analyzes the scenario that the passenger transportation business is concentrated in only one terminal in an emergency. This paper draws the following conclusions:

(1) Passenger transportation business capacity is restricted by each activity process capacity. Passenger business capacity analysis can be achieved in three steps. First, sort out the activity process of passenger transportation business and determine the sequence of each activity process; then determine the standard capacity per unit time of each activity process; and finally build an analysis equation model based on the queuing theory.

(2) The weak activity process that hinders the increase in domestic flight passenger transportation business capacity of A airport terminals is passengers' luggage check. increasing passenger luggage check counters, self-service equipment and personnel can improve the capacity of passenger luggage check, which can finally improve the domestic flight passenger transportation business capacity. The passenger security check at the T1 and T2 terminals is also a potential congestion point. It is necessary to increase security check channels and security check personnel to improve passenger security check capacity.

(3) When an emergency occurs, only T1 terminal of A airport keeps operation. If all resources are available, T1 terminal can not take domestic flight passenger transportation business of its own and T2 terminal. The luggage check activity processes is an obvious blocking point. If all activity processes of the domestic flight passenger transportation business need to be operated manually, T1 terminal can not take domestic flight passenger transportation business of its own and T2 terminal either. At this time, the four activity processes, passengers check-in, passengers' luggage check, passengers' luggage security check, and passengers security check, are all blocking points

References

[1] L. N. Shi, H. Y. Zhou and F. Yu, "Passenger departure simulation analysis in airport terminal," Computer Engineering and Design, vol. 30, no. 2, pp. 449-452, 2009.

[2] X. L. Ran and J. Wang, "Design of baggage system in Pudong airport T2 terminal building based on passenger analysis," Industry of China, no. 3, pp. 53-55, 2012.

[3] J. K. Liu, "Reestablishing safety production based on business continuity management (BCM) system," Journal of Xi'an University of Science and Technology, vol. 40, no. 3, pp. 374, 2020.

[4] J. Junttila, "A business continuity management: the search for an ISO22301 compliant BCM maturity model.," University of Turku, 2014.

[5] S. A. Torabi, H. R. Soufi and N. Sahebjamnia, "A new framework for business impact analysis in business continuity management (with a case study)," Safety Science, vol. 68, pp. 309-323, 2014.
[6] K. Randeree, A. Mahal, A. Narwani, "A business continuity management maturity model for the UAE banking sector," Business Process Management Journal, vol. 18. No. 3, pp. 472-492, 2012.
[7] I. Sawalha and A. J. Meaton, "Business continuity management in Jordanian banks: Some cultural considerations," Risk Management, vol.14, no. 4, pp. 301-324, 2012.
[8] R. Rai and L. Mohan, "Business continuity management in banks," Journal of Internet Banking and Commerce, vol. 11, no. 2, pp. 8-13, 2006.
[9] G. Parise, L. Parise, M. Allegri, A. D. Marco and M. A. Anthony, "Operational resilience of hospital power systems in the digital age," IEEE Transactions on Industry Applications, vol. 57, no. 1, pp. 94-100, January-February, 2021.