Research on Influence of Airport Runway Capacity Based on RECAT

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Abstract

The implementation of aircraft wake reclassification control interval experiment is to reclassify different aircraft types according to different aircraft parameters and standards. On the premise of ensuring safety, it is of great significance to further reduce the safety interval between aircraft and enable the airspace to accommodate more aircraft to improve the safety and efficiency of civil aviation operation. Firstly, this paper introduces the operation of wake reclassification at home and abroad, and summarizes the basic theoretical research of aircraft wake reclassification. On the basis of relevant research, taking the aircraft type and time of landing in one day at Zhengzhou Xinzheng airport as the research object, and on the basis of relevant assumptions, the current standard, recat-cn and recat-eu average wake interval models are established. The model simulation results show that under the standard of recat-cn that the wake interval of the same type is 2.5nmile (4.63km), the wake interval of Zhengzhou Xinzheng airport can be reduced by 21.17%; If recat-eu standard is tried out, the wake interval of Zhengzhou Xinzheng airport can be reduced by 23.36%. The data show that recat not only improves the capacity of Xinzheng airport to a certain extent, but also improves the operation efficiency of the airport. At the same time, the sensitivity analysis method is used to study the front and rear approach combination of different aircraft in Xinzheng airport. It is concluded that recat has a certain stability for the airport runway capacity and efficiency, and has a positive significance for the airport runway capacity and operation efficiency.

Keywords

Wake interval; RECAT-CN; Runway capacity; Mean wake interval model.

1. INTRODUCTION

In recent years, China has also accelerated the research, experiment and trial operation of wake interval reduction. Nie Runtu and others calculated and analyzed the airport capacity improvement based on the recat schemes of different foreign standards, and studied the capacity improvement rate when the number of different aircraft types changes [1]; Li Yaowei conducted a collision safety analysis on the aircraft wake reclassification to reduce the wake interval. The results show that after the wake interval is reduced, the collision risk value is less than, and the aircraft wake reclassification to reduce the wake interval is safe [2]; Zuo et al. Expounded the development of wake reclassification and summarized the current wake reclassification standards in different countries and regions [3]; By comparing the differences of recat standards between different countries and regions, Wei Zhiqiang and others analyzed the impact on the grass-roots capacity when the weighted average wake interval is the smallest and the impact of the change of the proportion of various types of models on the operation of

ISSN: 2472-3703 DOI: 10.6911/WSRJ.202206_8(6).0058

recat [4]. Li Zhilin analyzed the flight takeoff and landing models of Chongqing Jiangbei Airport and concluded that recat plays a certain role in improving the capacity of Jiangbei Airport [5].

The research on recat abroad started earlier, and the concept of wake reclassification was first put forward by the European navigation safety organization in 2007. Subsequently, the FAA also launched relevant theoretical and conceptual research in 2009. In 2014, t kolos Lakatos found in the study of three airports in Boston, Philadelphia and Newark that when heavy aircraft and Boeing 757 aircraft are mainly used, the wake vortex separation limits the runway capacity, and the runway capacity and the setting of fast departure Lane also have a great impact [6]. A jimenezgarcia first tried to apply recat-eu to the fixed wing aircraft classification of helicopters in 2017. Based on the classification of helicopter rotor diameter and weight, combined with the comparison of wakes of different classes of fixed wing aircraft and helicopters. The results show that recat-eu is suitable for helicopter classification in the approach phase [7]. J ROA conducted further research on the workload of the controller caused by the dynamic wake interval in the third stage of recat in 2018 [8].

2. RESEARCH ON THE OPERATION OF RECAT

FAA (Federal Aviation Administration of the United States) and Eurocontrol (OSCE) started their research on recat earlier, formulated corresponding standards, gradually promoted the wake reclassification standard, and carried out pilot operation in many airports in Europe and the United States. The results of pilot operation show that the wake reclassification standard (recat) plays a positive role in airport runway capacity, operation safety and efficiency. After 2015, the United States, Europe and other countries further revised the recat standard and the provisions on wake interval on the basis of relevant research, thus forming recat2.0, CWT, recat-eu and other new recat standards.

2.1. Research on the Operation of ICAO RECAT

In the 1970s, the International Civil Aviation Organization (ICAO) established wake interval standards based on the prevailing meteorological conditions, air traffic control methods and airport runway usage. Currently, with the exception of a few major aviation powers such as the United States and the member countries of the European Navigation Safety Organization, most ICAO member countries adopt the wake interval standard specified in Doc4444.

In view of the positive role of RECAT in improving runway operational efficiency, ICAO held its twelfth Air Navigation Conference in November 2012 and proposed to modify GANL (Global Air Navigation Plan) and ASBU (Aviation System Block Upgrade Plan) based on the wake interval standard of ICAO Doc4444, and reached a strategic intention agreement on the above. Based on the research results of various countries, ICAO divides the development of RECAT into three stages:

In the first stage, the current ICAO wake interval standards are optimized into six categories. The second phase uses a static pairing mechanism instead of the existing wake interval classification and matches each pair of aircraft with a safe, appropriate, and fixed minimum wake interval. The third stage is the dynamic wake interval, which determines the minimum required wake interval for an aircraft in real time based on flight parameters such as aircraft weight and weather conditions. Maximize the use of runway resources. The International Civil Aviation Organization plans to complete the time-based wake interval standard by the end of 2023.

2.2. Research on RECAT Operation in Europe

The concept of wake reclassification was first proposed by the European Aeronautical Safety Organization in 2007 to reclassify aircraft after their wakes have been assessed. Through the

ISSN: 2472-3703 DOI: 10.6911/WSRJ.202206_8(6).0058

combination of each type, different combination modes are obtained, and the minimum safety interval of different combination modes is calculated and analyzed in detail, which makes the standard of wake interval between different types more accurate and reasonable, so as to shorten the wake interval, improve aircraft safety, increase the efficiency of airport runway, and create more economic benefits. In 2009, the European Aeronautical Safety Organization and the Federal Aviation Administration jointly conducted a feasibility study of wake reclassification. It is considered that the wake reclassification is a feasible method to shorten the wake interval and has high research value.

In 2013, the European Aeronautical Safety Organization conducted an independent study of the RECAT-EU project on the basis of a collaborative study with the Federal Aviation Administration of the United States. Taking into account the important factors such as the speed, weight and wingspan of the aircraft, some new technologies and schemes proposed by European aviation service providers are systematically studied by optimizing the categories of various types in RECAT-EU. Through theoretical calculation and analysis, it is shown that RECAT-EU reduces the wake interval and improves the operating efficiency significantly while ensuring safety.

Comparing with FAA standards, we find that there are slight differences, mainly from the B752 and B753 aircraft of class C (Lower Heavy) in RECAT-EU, which are classified as class D (Large) in FAA. Class E aircraft B732, B733, B734, B735 in RECAT-EU are classified as Class D in FAA. The RECAT-EU wake classifier is shown in Table 1.

Table 1. RECAT-EU Wake Classifier

Category	Name	Airplane type							
A	Supper Heavy	A388	A124	-	-	-	-	-	-
B	Upper Heavy	A332	A333	A343	A345	A346	A359	B744	B748
		B772	B773	B77L	B77W	B788	B789	IL96	-
C	Lower Heavy	A306	A30B	A310	B703	B752	B753	B762	B763
		B764	B783	C135	DC10	DC85	IL76	MD11	TU95
D	Upper Medium	A318	A319	A320	A321	B736	B737	B738	B739
		C130	IL18	MD81	MD82	MD83	MD87	MD88	TU16
E	Lower Medium	AT43	AT72	B712	B732	B733	B734	B735	CL60
		CRJ1	CRJ2	CRJ7	CRJ9	E135	E145	E170	E190
F	Light	FA10	FA20	D328	E120	BE40	JS41	LJ60	C750

The test run of RECAT-EU shows that RECAT-EU can increase the capacity of the runway by about 5% during peak hours, depending on the flight combinations of the airports. At the same speed, the total flight time for take-off and landing of an aircraft can be reduced, and the controller has more flexibility to exercise effective control. It ensures that airport operations recover quickly from adverse conditions, thereby reducing delays.

2.3. Research on RECAT Operation in the US

The Federal Aviation Administration considers that the classification of wake interval based on the three maximum takeoff weights of heavy, medium and light in the International Civil Aviation Organization Doc4444 is relatively conservative and limits runway capacity. In 2009, the Federal Aviation Administration of the United States initiated a feasibility study of wake reclassification jointly with the International Civil Aviation Organization and the European Aviation Safety Organization. The respective RECAT standards and corresponding wake interval standards have been established successively.

In November 2012, Memphis Airport became the first airport in the world to implement RECAT 1.0. After a 6-month trial run, the Federal Aviation Administration, Memphis Airport

ISSN: 2472-3703 DOI: 10.6911/WSRJ.202206_8(6).0058

Tower, Federal Express and other agencies or companies evaluated the airport capacity during the 6-month trial run. The data analysis results show that the takeoff capacity of the airport runway increases by 22% and the landing capacity increases by 15%. FedEx's flight intervals in the United States will be reduced by 85% and its departure queue time by 38%. The average take-off capacity during peak flight times increased by 7 sorties per hour, and no pilot reported encountering a wake [18]. Therefore, RECAT 1.0 can help to improve the capacity of airport runway while ensuring safety. It has been extended to international airports such as Louisville and Miami since early 2013.

In June 2014, the Federal Aviation Administration officially released the Wake Reclassification Scheme and the New Wake Interval Standard (RECAT1.5), which classifies aircraft into six categories and equips them with new separation distances. After a period of operation, the Federal Aviation Administration and some universities conduct research based on operational data. RECAT1 was revised in mid-February 2016. 5. Some standards are updated and the latest regulations are issued. In the next two years, the United States from JO7110. 659A improved to JO7110. 659C is upgraded to JO7110. Regulations such as 123, the standards for wake reclassification have been continuously improved, and the standards for wake interval have also been continuously improved to be closer to the actual operation. Some of the interval criteria are lower than before. After safety factors, the small interval standard is raised, which also indicates that the decrease of wake interval needs further study.

In August 2016, the Federal Aviation Administration released the second stage of the wake reclassification scheme (RECAT2.0), which further classifies the aircraft into seven A-G classes. The major airlines operating in the United States are equipped with appropriate safe intervals. In June 2018, the Unified Wake Interval Standard (CWT) was released, and improvements to CWT were released in August 2019, with the latest version being implemented immediately. The new version divides the aircraft into nine categories A-I, updating the minimum wake interval standard between aircraft. On October 10, 2019, the implemented model index was published, which specifies RECAT 1.5, RECAT 2.0 and CWT.

2.4. Research on RECAT Operation in China

In 2015, the Civil Aviation Administration of China announced the Development and Implementation Strategy of the China Civil Aviation System Block Upgrade (ASBU). The document planned the development goals of China's aviation system and defined the development direction of RECAT-CN, the reclassification of China's wake. For this reason, the Air Traffic Administration of the Civil Aviation Administration of China has demonstrated the feasibility of promoting the application of the wake reclassification technology in China according to the actual conditions of our country, and has jointly studied the conditions for implementation and the Suggested Schemes in several universities, and concluded that the wake reclassification is feasible. After that, on the basis of demonstrating the security of RECAT in Europe, America and other countries, combined with the actual operation situation at home and abroad, the characteristics and relevant requirements of civil aviation operation in China, the standards of aircraft wake reclassification in China (RECAT-CN) are formulated, and the test operation is started.

On December 5, 2019, the Bureau began to pilot the two airports, Baiyun Airport and Baoan Airport, and started the pilot operation of aircraft wake reclassification control. This is the first practice of RECAT technology in China. By the end of 2020, the test will run smoothly and safely. The number of flights taking off and landing under this standard has reached the scheduled standard, accounting for about 50% of the two aircraft participating in the test run, and the average reduction rate of the wake interval before and after the test run is about 20%. The two controllers were skilled in applying the RECAT-CN model classification method and mastering the corresponding new interval standards. The pilots of airlines such as Southern Airlines,

ISSN: 2472-3703 DOI: 10.6911/WSRJ.202206_8(6).0058

Hainan Airlines, Shenzhen Airlines, Shunfeng Airlines, Federal Express, UPS and so on who participated in the test run also have a basic understanding of the relevant standards and requirements for the test run.

On December 31, 2020, with the new round of ICAO information update coming into effect, the Bureau began to operate in Beijing Capital, Daxing Airport, Shanghai Hongqiao Airport, Pudong Airport, Hangzhou Xiaoshan Airport, Nanjing Lukou Airport, Zhengzhou Xinzheng Airport, Wuhan Tianhe Airport, Chengdu Shuangliu Airport, Chongqing Jiangbei Airport, Kunming Changshui Airport and Xi'an Xianyang Airport. A total of 12 airports have undergone pilot operations for aircraft wake reclassification. With the continuous research and improvement of RECAT-CN operation. After the new standard has been put into operation, it is bound to continuously improve the operational efficiency, and its economic role will become more prominent.

3. CONSTRUCTION AND SOLUTION OF AVERAGE WAKE INTERVAL MODEL

3.1. Basic Theory of Aircraft Wake Reclassification

1. Aircraft wake reclassification concept

Reclassification of aircraft wake (RECAT-CN) is a new control technology for civil aviation in China. The new aircraft wake reclassification is designed to effectively improve the operational efficiency of airports on the basis of ensuring the safe wake interval between the front and rear aircraft. The new standard subdivides heavy aircraft in the current standard from a single class H into two classes B and C, which enables the system to have more definitions of airplane type and wake, and provides more combinatorial options for controllers.

2. Aircraft Wake Reclassification Criteria

The standard of wake interval depends on the type of aircraft. In RECAT-CN, the types of aircraft are divided into the following five categories according to the maximum allowable take-off weight and wingspan of the aircraft. The maximum allowable take-off weight, wingspan regulations and typical types are shown in Table 2:

(1) Super heavy machinery: its wake type identifier is J;

(2) Heavy: Its wake type identifier is B;

(3) Heavy: Its wake type identifier is C;

(4) Medium machine: its wake type identifier is M;

(5) Light: Its wake type identifier is L.

The B757 series (including B757-200, B757-300, etc.) is divided into medium-sized aircraft.

Table 2. Recat-cn classification method

Category	Wingspan/m	Maximum take-off weight/t	Typical aircraft type
J	≥75	≥136	A380
B	54-75	≥136	B748, B788, B77W, B772, A338, A339, A35K, A359etc
C	≤54	≥136	B762, B763, A300etc
M	—	15-100	Consistent with ccar-93-r5
L	—	15-100	Consistent with ccar-93-r5

3.2. Establishment of Mean Wake Interval Model

1. Model assumptions and parameters

According to Bernoulli's law of large numbers, when a large number of experiments are repeated, the final frequency will be infinitely close to the probability of the experiment. Therefore, under the condition of large sample test, the landing frequency of the aircraft can be

ISSN: 2472-3703 DOI: 10.6911/WSRJ.202206_8(6).0058

similar to the arrival probability of the aircraft at a certain airport. The aircraft in the terminal area are generally sorted according to the principle of arrival order. Based on the above theory, this paper assumes that the approach sequencing process of an airport terminal area is a random event. The probability of a certain type of aircraft becoming a front aircraft or a rear aircraft is equal.

In addition, the wake separation distance between similar aircraft in ccar-93-r5 is usually 6 km. However, in the United States, Europe and other countries, the minimum radar separation distance is 2.5 nautical miles. Based on the above information, it is assumed that the minimum radar interval parameter of recat-cn is 2.5 nautical miles (1 nautical mile = 1.852 km), i.e. 4.63 km.

2. Average wake interval function

According to the current standards, recat-cn and recat-eu wake interval standards and the probability of front and rear aircraft models under the above three wake interval standards, the average wake interval model of aircraft in the terminal area is established:

$$D = \sum_i^n \sum_j^n S_{ij} P_{ij} \tag{1}$$

Where:

n, the number of aircraft classified.

P_{ij}, the probability of this event when the former aircraft is a type aircraft and the latter aircraft is a type aircraft.

S_{ij}, under the above three different wake separation standards, the minimum wake separation distance to be maintained if the front aircraft is a type aircraft and the rear aircraft is a type aircraft.

$\mathcal{D}$, the average wake separation distance required by all aircraft in a day.

The wake interval can be obtained by weighted average of and. Represents the average wake separation distance required by all aircraft in an airport within 24 hours. The smaller the value, the greater the runway capacity of an airport under the condition of existing airspace resources.

3.3. Solution of Mean Wake Interval Model

According to the model characteristics and relevant formulas. The solution of this model is divided into the following four steps:

1. Approximate the model as a mathematical model;
2. Simplify the model;
3. Define the parameters of the model;
4. Substitute relevant data into the model for solution.

Because this model cannot be solved without actual mathematics, and specific values cannot appear. Therefore, the model solution needs to be based on a certain data base.

4. CASE ANALYSIS

4.1. Data Combing of Xinzheng Airport Based on RECAT

This paper collects 323 incoming flights from Nov. 29, 2020 to Nov. 24, 2020 at Xinzheng Airport. After excluding flight information such as sharing and canceling in the data, 313 flights were totally collected. The sorties statistics for each type are shown in Figure 1.

ISSN: 2472-3703 DOI: 10.6911/WSRJ.202206_8(6).0058

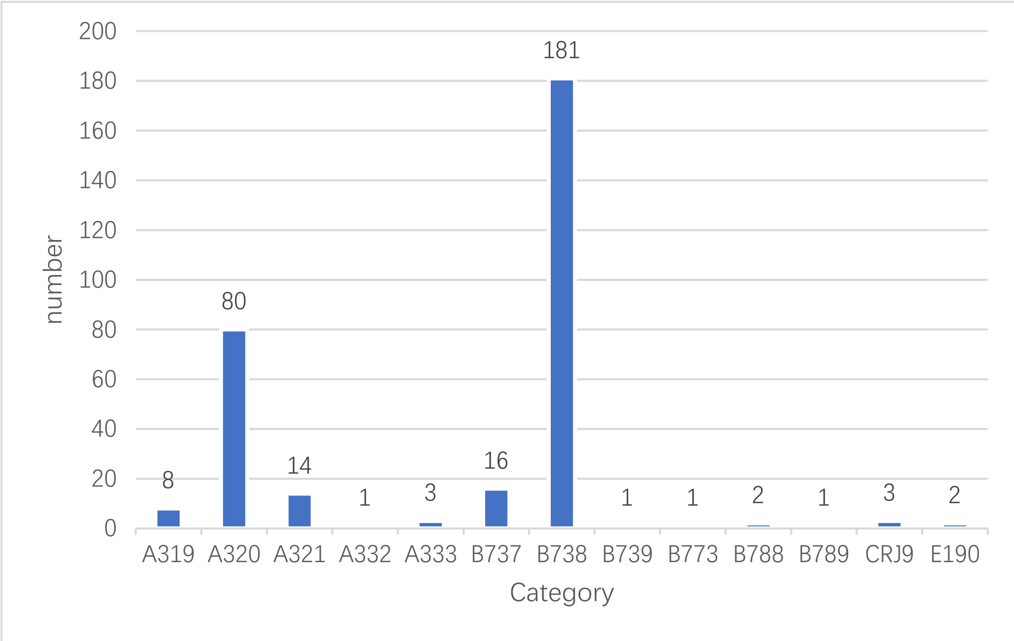

Figure 1. Distribution of flight types that landed on Nov.29 at Xinzheng Airport

On November 29, 2020, Beijing Time, Zhengzhou Xinzheng International Airport has good weather conditions, with minimum visibility less than 5 km and wind speed less than 3 meters per second. And more than half of the day is CAVOK weather, the airport has no operating restrictions.

According to the CCAR-93-R5, RECAT-CN and RECAT-EU standards, every flight information that landed within 24 hours on November 29 in Zhengzhou Xinzheng Airport is sorted out, and the classification statistics of type and category are made to calculate the proportion of total landing sorties.

Then classify and visualize the landing models of Xinzheng Airport, as shown in Figure 2, Figure 3 and Figure 4:

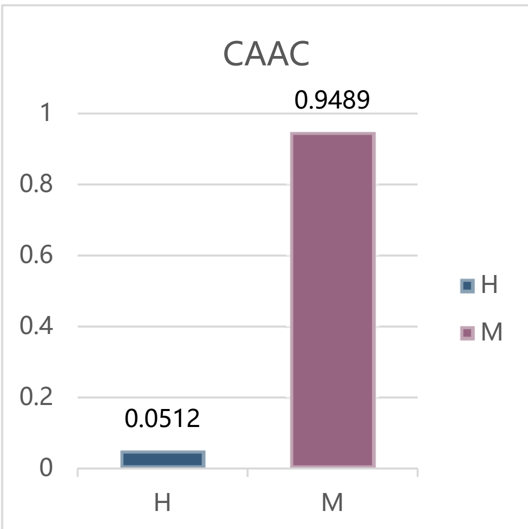

Figure 2. Proportion of current standard landing aircraft after reclassification

ISSN: 2472-3703 DOI: 10.6911/WSRJ.202206_8(6).0058

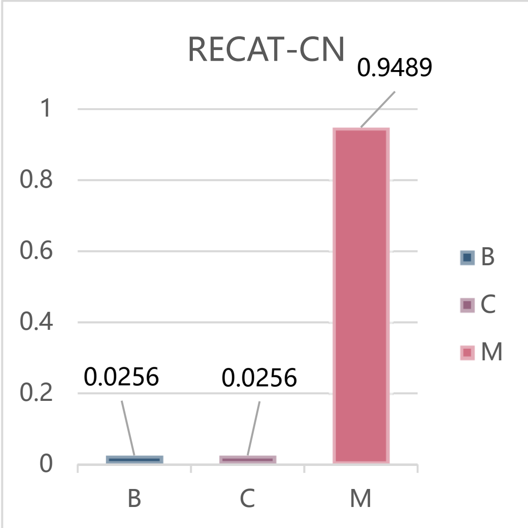

Figure 3. Proportion of RECAT-CN standard landing aircraft after reclassification

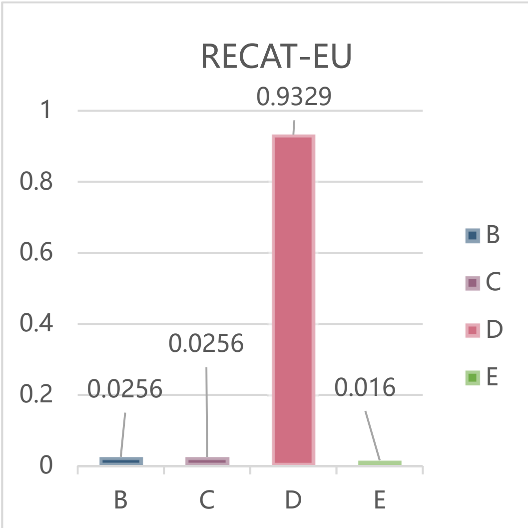

Figure 4. Proportion of RECAT-EU standard landing aircraft after reclassification

4.2. Calculation and Analysis of Average Wake Interval Model

Based on the above model assumption, the combined probabilities of the front and back types can be summarized into discrete joint probability density tables under three wake interval criteria. From the calculation, we can see that the average aircraft interval under CCAR-93-R5 (current standard) is 6.166 kilometers. The average wake interval after a pilot REACAT-CN with a minimum interval of 2.5 nautical miles (4.63 kilometers) is 4.86 km, which is about 21.17% higher than the current standard. If the average wake interval of the RECAT-EU standard is 4,724 km on trial, the current standard airport interval can be reduced by 23.36%. As shown in Figure 5:

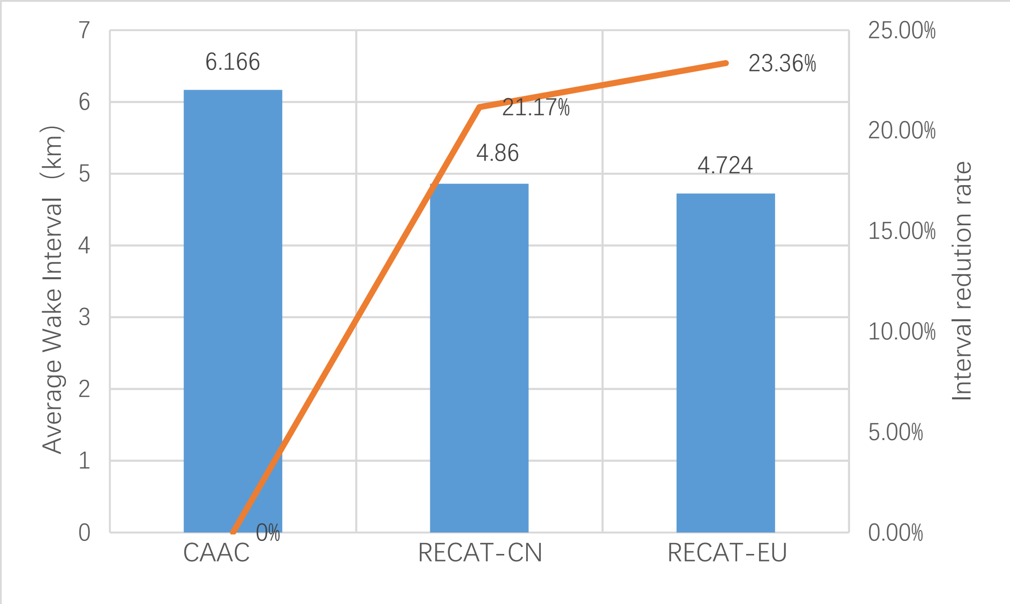

Figure 5. Average wake interval distance and wake reduction rate for aircraft under three wake interval criteria

4.3. Sensitivity Analysis

In the systematic evaluation of schemes, sensitivity analysis is generally used to study the corresponding changes of evaluation results when the distribution weight changes within a certain range. In this paper, the index weight sensitivity analysis method is used to analyze the stability of a certain airport after the implementation of RECAT. This demonstrates the validity of the application of RECAT to improve airport capacity.

As the number of heavy aircraft (H heavy aircraft in ICAO, B in RECAT-EU), B748, B77W, A338, etc.) and medium (D) and light aircraft (E) take-off and landing increases, the airport runway capacity will continue to decrease. Especially with the increase of Class D aircraft (such as A320neo, B737 series), the airport capacity increase rate decreases gradually (similarly, with the increase of class E and F aircraft sorties, the airport capacity increase rate decreases gradually). As the general heavy-duty aircraft (ICAO classified as heavy aircraft, RECAT-EU classified as C, actual operation classified as B757 and B767) corresponds to two categories of heavy-duty aircraft (H) and medium-sized aircraft (M) in ICAO standard, the situation analysis shows that when the number of class C aircraft sorties corresponding to heavy aircraft increases, the airport capacity lifting rate increases gradually, and when the number of class C aircraft sorties corresponding to medium-sized aircraft increases, the airport capacity lifting rate decreases gradually.

5. CONCLUSION

This paper first introduces the background of wake reclassification, as well as the current research status and corresponding standards in the United States, Europe and the International Civil Aviation Organization. Secondly, the wake reclassification method of civil aviation in China (RECAT-CN) is introduced. Comparing the differences between the new and old operating standards, reorganizing and classifying the model data. Then, based on the relevant assumptions, the current standard, RECAT-CN, RECAT-EU average wake interval model are established with the aircraft type and time of landing in one day in Zhengzhou Xinzheng Airport as the research object. On the basis of the above, the stability of the airport capacity improvement efficiency is studied by changing the different aircraft approach and approach

ISSN: 2472-3703 DOI: 10.6911/WSRJ.202206_8(6).0058

composition at Xinzheng Airport using sensitivity analysis method, and the main conclusions are as follows.

1. Wake reclassification technology can greatly improve the runway capacity and operational efficiency of the airport. If RECAT-CN uses the same type of wake interval of 2.5 nmile (4.63 km), the wake interval of Xinzheng Airport can be reduced by 21.17%. If RECAT-EU standard is used, the wake interval of Xinzheng Airport can even be reduced to 23.36%. At the same time, when the aircraft's front and rear models change, its capacity increase rate also has some stability.

2. The wake separation distance between aircraft of the same class in CCAR-93-R5 is usually 6 kilometers. However, countries such as the United States and Europe use a minimum radar interval of 2.5 nautical miles. Zhengzhou Xinzheng International Airport operates most of the aircraft suitable for class M aircraft under RECAT-CN classification. When the original minimum wake interval of 6 km is continued, the reduction of the wake interval for Xinzheng Airport will not increase much, only 1.3%.

3. Under the current combination of aircraft types in China, when RECAT is used, the wake interval of heavy or super heavy aircraft (Super, Heavy in CCAR-93-R5 standard, J, H in RECAT-CN standard) will be reduced significantly and the runway capacity will be improved.

ACKNOWLEDGMENTS

1. Fund Project: Henan University Laboratory Work Research Association project (ULAHN202145).

2. Fund Project: Henan science and technology research project (222102210093).

REFERENCES

[1] Nie Run Rabbit, Li Bingbing. Impact Analysis of New Wake Classification Criteria (RECAT) on Runway Capacity [J]. Aeronautical Computing Technology, 2015,45(04): 4-7.

[2] Li Yaowei. Wake Interval Reduction and Collision Safety Analysis [D]. Nanjing University of Aeronautics and Astronautics, 2015.

[3] Left Qinghai, Yang Fan, Pan Weijun. A review of the development of civil aircraft wake reclassification [J]. Henan Science and Technology, 2020,39(26): 65-70.

[4] Wei Zhiqiang, Mou Mingjiang, Li Zhiyuan. Difference comparison and computational analysis of RECAT interval standard [J]. Aeronautical Computing Technology, 2017,47 (04): 6-9+13.

[5] Li Zhilin, Pan Weijun, Zhang Xiaolei, Ran Bin. Prediction and Analysis of Implementation Effect of Jiangbei Airport Terminal Area Based on RECAT [J]. Journal of Civil Aviation, 2019,3(03): 68-72+28.

[6] Kolos-Lakatos T . The Influence Of Runway Occupancy Time And Wake Vortex Separation Requirements On Runway Throughput[C]. massachusetts institute of technology, 2014.

[7] Jimenezgarcia A ,Barakos G N , Treve V ,et al. Helicopter Wake Encounters in the Context of RECAT-EU[C].2017.

[8] Roa J . Air Traffic Controller Additional Work Load as a Result of Aircraft Dynamic Separations[C]// International Conference on Applied Human Factors and Ergonomics. 2018.