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The Characteristics of Flight Delay in China

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Abstract: *Flight delay is a global problem. With the development of air transport, flight delay is particularly serious in China. The definition of delay is an evolutionary process in China. This paper discusses the definition of delay from three aspects: the benchmark of delayed time, the benchmark of actual departure/arrival time and the coverage of delay statistics. An inappropriate definition of delay may lead to inconsistencies between statistical data and passenger perceptions before 2017. From a macro perspective, this paper uses first-hand data to reveal the law of on-time performance (OTP) at industry-level and finds that OTP of airports is always better than that of airlines. From a micro perspective, Route-level analysis shows that airline's arrival OTP is better than that of departure OTP, but in terms of the average delayed time, the opposite is true. Further research on the distribution of delayed time shows that, whether arrival or departure flight, delays within 30 minutes rank the highest proportion. Finally, there is no necessary connection between delay and flight distance.*

Keywords: *flight delay, on-time performance, delayed time, China*

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I. Introduction

After more than twenty years of rapid development, air transport in mainland China has become the world's second largest air transport market. In 2017, the whole industry completed a total Revenue Ton Kilometer (RTK) of 108.3 billion, with 229 certified transportation airports, 3,296 registered commercial aircraft, 4,418 scheduled air routes and 4.04 million passenger flights. However, with the rapid growth of transportation scale, the problem of flight delay is becoming more and more serious, and passengers' complaints about flight delays have become one of the most important obstacles restricting the development of the industry.

This paper collects the original flight delay data of China's air transport industry at both industry and route level in recent years. Through data processing and analysis, it attempts to summarize the characteristics of flight delays in China and provide a basis for future management of flight delays. The framework of this paper is as follows: Part Ⅱ reviews the relevant literature in this field. Part Ⅲ discusses the definition of flight delay and its evolution in China. Part Ⅳ is data and analysis. It calculates and analyses indicators such as on-time performance (OTP) and the duration of delay to reveal the law of flight delays. Part Ⅴ is conclusion.

II. Literature Review

Flight delay is a global problem, which has attracted the attention of many researchers in recent years. Some scholars have conducted relevant studies from different perspectives.

The first question people would ask is that what are the affecting factors of flight delays. Abdel-Aty et al. (2007) find that time of day, day of week, season, flight distance, precipitation and scheduled time intervals between successive flights were significantly correlated with arrival delay [1]. But Zamkova al. (2017) argue that flight delays are most frequently caused by delays of previous flights of the same plane. They are the main culprit of long delays [2].

Passengers don't like flight delays, because once a flight is delayed, the quality of service that passengers receive decreases. Mazzeo (2003) finds that both the prevalence and duration of flight delays are significantly greater on routes where only one airline provides direct service. That is to say, additional competition is correlated with better OTP [3]. So what will Airlines do? Baumgarten, Malina and Lange（2014）find that airlines use buffer times to mitigate passenger-perceived delays against schedule that would, without buffers, arise from more complex network operations [4]. Forbes, Lederman and Wither（2018）further point out that airlines can improve 15% of their OTP by simply increasing their scheduled flight times 1.4-2.3 min longer [5].

Flight delays can also have a series of adverse impacts on the air transport market. Forbes (2008) presents evidence that better OTP increases passengers' willingness-to-pay for air travel. He finds that prices fall by $1.42 on average for each additional minute of flight delay, and that the price response is substantially larger in more competitive markets [6]. Britto et al. (2012) further show that flight delays reduce passenger demand and raise airfares, producing significant decreases in both consumer and producer welfare. From the airline's point of view, flight delays increase costs [7]. Ball et al. (2010) finished a report which analyzes a variety of cost components caused by flight delays, including cost to airlines, cost to passengers, cost of lost demand, as well as the indirect impact of delay on the US economy. The total delay impact (TDI) project team estimates that the total cost of all US air transportation delays in 2007 was $32.9 billion [8]. Peterson et al. (2013) determine the economic costs of delayed flights, including the direct effects of increased airline cost and the indirect effects of lost labor productivity for business travelers, an opportunity cost of time for leisure travelers, and changes in consumer spending on travel and tourism goods and services [9]. Flight delays also pose challenges for government authorities. Bishop et al. (2011) find that an obvious caveat of U.S. DOT counting flight delays is that the duration of delay plays no role in the delay count. So they propose an aggregate delay measure that is based on three widely acceptable passenger preferences [10].

In China, there are also some scholars who have carried out research on flight delays. Kong and Chow (2015) show that an increase in actual OTP reduces customer complaints. However, an increase in expected OTP significantly raises customer complaints [11]. Tsionas et al. （2017） report on the performance assessment of Chinese airlines from 2006 to 2014 using a stochastic distance function where technical efficiency and a measure of flight delays follow a joint structural autoregressive process. The results suggest a mutual dependence between technical efficiency and delays [12]. Chen et al. (2018) use the input–output method and the Ghosh model to analyze the indirect economic impacts of flight delays on China’s economy [13].

Although these studies have covered many aspects, so far, few researchers has fully revealed the characteristics of flight delays in China from both industry and route level.

III. Definition of Flight Delays in China

The Civil Aviation Administration of China (CAAC) updates the definition of flight delays every few years, which makes the definition of flight delays in China change irregularly. These changes are reflected in three aspects:

The first is benchmark of delayed time. In China, the benchmark of delayed time to define flight delays varies from 0 to 30 minutes. Historically, 0, 5, 10, 15, 20, 25 and 30 minutes have been used as benchmark of flight delays.

The second is benchmark of actual departure/arrival time. Flight delays are usually defined as the time gap between actual departure/arrival time and scheduled departure/arrival time. The scheduled time is announced in advance by the flight schedule, so it is clear and fixed. But the benchmark of actual arrival/departure changed several times in the past twenty years, which is crucial for identifying flight delays. In China, door opening time, landing time and chocks-on time have been used as the benchmark for actual arrival. Correspondingly, take-off time, door closing time, chocks-off time have been used as the benchmark for actual departure. The final delayed time may be quite different under different benchmark, which also results the officially released OTP statistics to be inconsistent with passenger perceptions.

The third is the coverage of delay statistics. Before 2017, officially released OTP data covers both arrival and departure at the same time. That is to say, either arrival or departure meets the conditions of on-time, the flight was counted as on-time, which may overestimate the OTP In China. However, the OTP data of arrival and departure flight are counted separately after 2017，which enables the officially released OTP data to better reflect facts and consumer perceptions.

The *On-time Performance Regulations on Flights*, which came into effect in 2017, have been improved in combination with the above three aspects in order to comply with international practice. Airline flight delays are divided into two types, one is called flight delay and the other is called flight departure delay. The former is defined that a flight arrived with chocks-on time 15 minutes more than the scheduled arrival time, so it is also called arrival delay. The latter means that a flight left with chocks-off time 15 minutes more than scheduled departure time. The new rules use the internationally accepted chocks-on/off time as a benchmark for actual arrival and departure. They make delay statistics more consistent with passenger perceptions and comparable internationally.

IV. Data and Analysis

In this part, we will discuss the characteristics of flight delays in China from industry-level and route-level. We will combine industry-level and route-level on-time performance data. These data are from official statistics and third-party commercial companies.

4.1 Characteristics of Flight Delay at Industry-level

In China, there are two main indicators for investigating flight delays, namely on-time performance of airlines and on-time performance of airports. The former mainly reflects both the departure and arrival flight delays from the perspective of airlines, and the latter reacts to departure flight delays from the perspective of airports support of flight. In this part, all data is from official Sources.

As shown in Fig. 1, we have collected the industry-level OTP data in China during the past ten years and found the following characteristics: OTP was first increased and then lowered. In 2004, OTP of the whole industry was 79.9%, and then slowly climbed to the highest point of 83.12% in 2007. Then it continued to decline. The lowest OTP in 2015 was only 68.33%. Since then, it had rebounded, but the OTP in 2017 was still only 71.67%, which was nearly 12% lower than the highest point ten years ago. Globally, flight OTP in China has been at a low level for a long time. In recent years, there has been a deteriorating trend, so governing flight delays has become a top priority. Second, with the expansion of transportation scale, the absolute number of non-punctual flights (including delayed, canceled and diverted) has increased dramatically. In 2004, the number of non-punctual flights for the whole industry was 238,407. But by the year of 2017, the number of non-punctual flights had reached 1.14 million, which was about 4.8 times that of 2004. Large numbers of non-punctual flights caused by delays and cancellations not only reduce the quality of flight services, lead to a decline in passenger satisfaction, but also increase the cost of consumers, enterprises and the whole society, and even have a negative impact on aviation safety. Third, OTP of small and medium-sized airlines is lower than that of large airlines. From 2009 to 2015, OTP of small and medium-sized Airlines is lower than that of large airlines (a little higher in 2016). The average OTP of small and medium-sized airlines during 2009-2016 is 70.24%, which is lower than large airlines (74.86%).

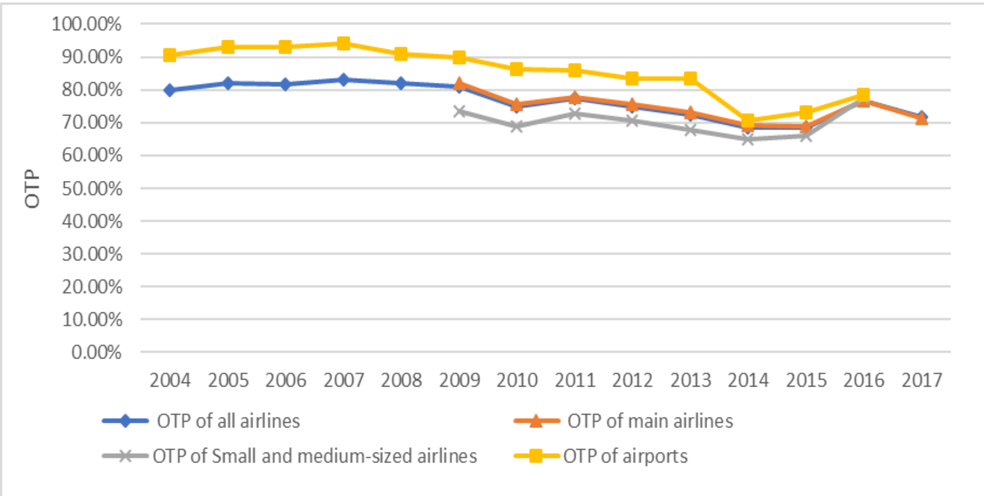


Fig. 1. Industry-level OTP in China

Source: 1. A Survey of Civil Aviation from Statistical Data; 2. Statistical Bulletin of Civil Aviation Industry Development

Another indicator of flight delay is on-time performance of airports. On-time departure is defined as a flight taking off within the standard airport taxiing time after the scheduled departure time (the standard airport taxiing time depends on the size of the airport, which is set by the CAAC). This indicator is used to reflect the flight support capability of the airport. OTP of airports is different from OTP of airlines departure. The latter is not measured by the standard airport taxiing time, but by whether a flight left with chocks-off time 15 minutes more than scheduled departure time.

Fig. 1 also shows the OTP of airports in China from 2004 to 2016. It is obvious that the airports OTP can be roughly divided into three stages: Before 2008, the OTP of major airports in China maintained at a high level of 90%, during 2009-2013 it dropped to more than 80%, and after 2014 it dropped to less than 80%. Departure delays are one of the main factors leading to subsequent flight delays and delay propagation. The deteriorating OTP of airports reflects the fact that departure delays of airlines are very serious.

Comparing the OTP of airports and airlines in Fig. 1, OTP of airports is found to be always higher than that of the airlines. That's why we have emphasized the difference in definition between airlines delay and airports delay. The OTP of airline is stricter than the OTP of the airport. Interestingly, in this case, if airports finds their OTP is not to bad, they will not have enough incentive to pay additional costs to further improve their

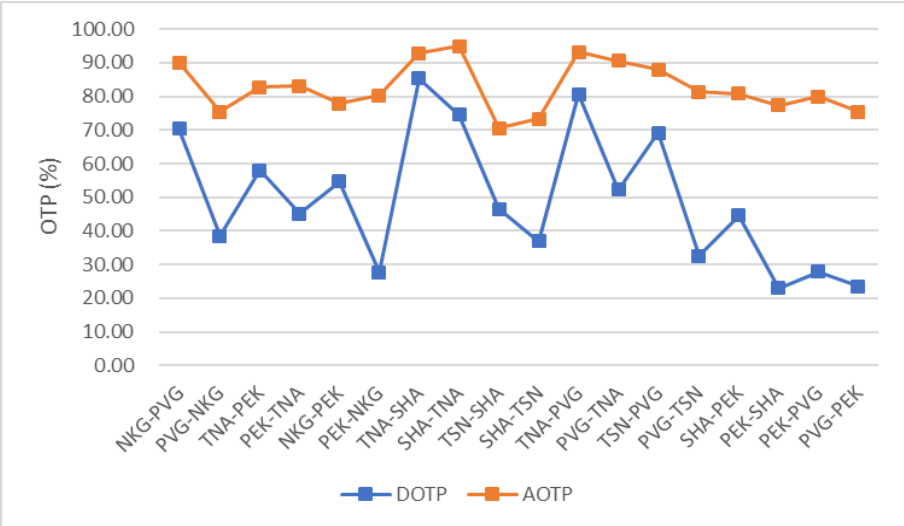
OTP. However this may further reduce departure OTP of airlines and subsequent arrival OTP of airlines and may increase delay propagation. If the authorities wish to keep these two different definitions, they should set higher OTP targets for the airports.

4.2 Characteristics of Flight Delay at Route-level

This paper chooses Beijing-Shanghai Corridor as a representative sample of flight delays at route-level. The reason for choosing this corridor is that it is in the eastern coastal area of China, connecting the two largest hub airports in China. Cities along the corridor have better economies and strong demand for air transportation. Therefore, the flight traffic is really heavy along the corridor, which may lead to more flight delays. Data comes from Variflight, a leading third-party business company for flight data in the world. All data are calculated according to the 15-minute delay definition and the period of data is 2017.08.13-2018.08.12.

4.1.1 Arrival/Departure OTP in Beijing-Shanghai Corridor

Fig. 2 illustrates the arrival/departure OTP of all direct flights in the Beijing-Shanghai Corridor. There are 9 city pairs, considering that outbound and inbound flights have different flight numbers, 9 city pairs means 18 city-to-city routes. All city names are expressed in accordance with the IATA city/airport code.



DOTP=Departure on-time performance AOTP=Arrival on-time performance

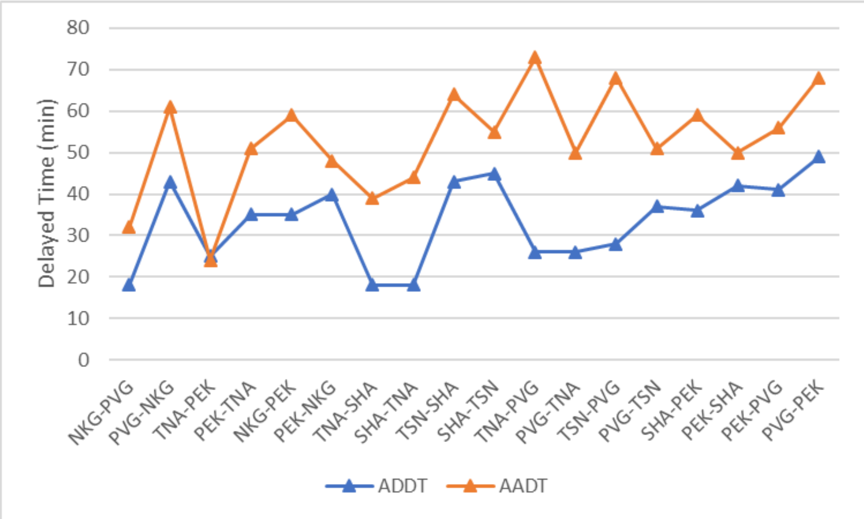
Fig. 2. Arrival/Departure OTP in Beijing-Shanghai Corridor

Obviously, DOTP is smaller than that of arrival on almost all routes. The average DOTP of all routes along Beijing-Shanghai Corridor is 48.90%, and the average AOTP of all routes is 82.61%, which means that the difference between the two has reached an astonishing 33.71%. This also shows that most of the delays occur in the phase of ground waiting before departure. For example, the delays caused by aircraft maintenance need to wait on the ground, most weather-caused delays and ATC-caused delays (air traffic control) also need to wait on the ground, which leads to lower DOTP. There may be two reasons why AOTP remains above 80%: On the one hand, there is less possibility of delay in the cruise phase of flight; On the other hand, passengers and regulatory authorities pay more attention to AOTP, thus forcing airlines to speed up after take-off, even by setting buffer time, that is to lengthen their schedule times, to improve their AOTP. However, there are costs associated with longer schedule times. For example, the loss of passengers (passengers usually prefer shorter flights), reduced utilization of aircraft, increased wage costs of crew members, etc. There is much space to improve AOTP with higher uncertainty, meanwhile the cost of adding buffer time to improve AOTP is high but controllable. In addition, DOTP from smaller cities to larger cities is usually higher than that of flights from opposite directions on the same city pair, which is consistent with the common sense that departure flights are more busy and delayed at large airports. But AOTP does not show a similar rule.

4.1.2 Arrival/Departure Delayed Time in Beijing-Shanghai Corridor

Fig. 3 shows the arrival/departure delayed time in Beijing-Shanghai Corridor. The data period and the routes involved are the same as those in Fig.1. The average delayed time is equal to the total delayed time divided by the total number of flights.

ADDT is less than AADT on most routes, except on TNA-PEK and SHA-NKG (both are only 1 minute higher). The mean value of ADDT in all routes along Beijing-Shanghai Corridor is 34.00 minutes while the mean value of AADT is 53.69 minutes and the difference between them is 19.69 minutes. Interestingly, although the overall OTP of arrival flights is better than that of departure flights, the average delayed time of arrival flights is higher once delays occur. Like the OTP, ADDT from smaller cities to larger cities is usually less than that from the opposite direction on the same city pair, which is also consistent with common sense. AADT does not show a similar rule.

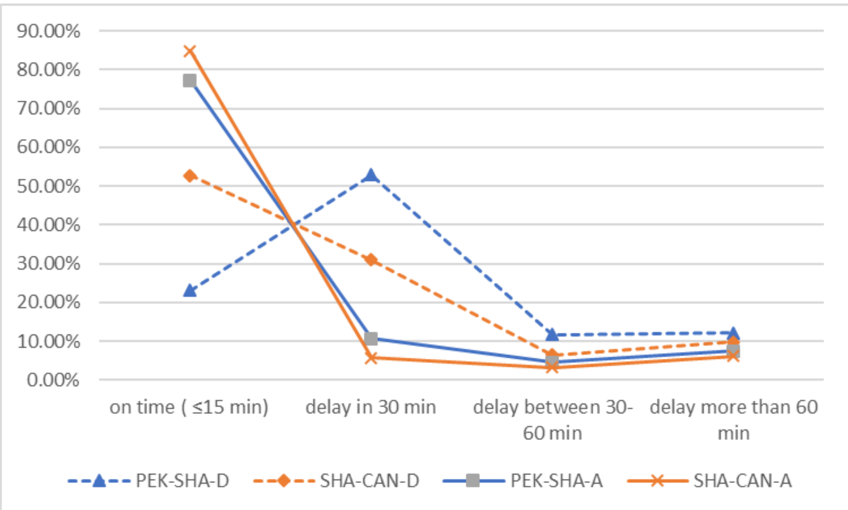


ADDT=Average departure delayed time AADT= Average arrival delayed time

Fig. 3. Arrival/Departure Delayed Time in Beijing-Shanghai Corridor

4.1.3 Distribution of Delayed Time

In order to further explore the characteristics of flight delays, we need to know the distribution of flight delays. Because of the huge amount of data, whole sample analysis may cost too much time. So we choose PEK-SHA route for analysis. The main reason for choosing this route is that it connects the two largest air hubs in China and is typical for research. In addition, in order to make a comparison, we add the SHA-CAN route to the analysis, which is also based on that CAN is the third largest air hub in China. The total number of flights on both routes are at the same level. During the period of 2017.08.13-2018.08.12, there were 14824 flights between PEK-SHA and 12228 flights between SHA-CAN.



PEK-SHA-D=Departure flight from Beijing to Shanghai Hongqiao
SHA-CAN-D= Departure flight from Shanghai Hongqiao to Guangzhou
PEK-SHA-A= Arrival flight from Beijing to Shanghai Hongqiao
SHA-CAN-A= Arrival flight from Shanghai Hongqiao to Guangzhou

Fig. 4. Distribution of Delayed Time

As shown in Fig. 4, the horizontal axis is divided into four cases: on-time, delay within 30 minutes, delay between 30-60 minutes and delay more than 60 minutes. The vertical axis the proportion of flights in each case to the total number of flights on the route. The departure OTP of both routes are less than the arrival OTP. SHA-CAN has less flights than that of BJS-SHA, so the departure and arrival OTP of SHA-CAN is higher, which is consistent with previous analysis. No matter departure or arrival, in the case of delays, delays within 30 minutes account for the highest proportion on both routes. As far as departure delay is concerned, the proportion within 30 minutes reached 52.94% and 32.99% respectively, which is significantly higher than departure delay between 30-60 minutes and more than 60 minutes. This further explains why departure OTP is lower. The main reason is that the proportion of short-term delays within 30 minutes is too high. Fig. 4 also explains to some extent why airlines are willing to increase buffer time within 30 minutes, because it can effectively improve OTP.

4.1.4 Relationship between Delay and Flight Distance

As is known to all, high-speed rail (HSR) transport is well developed in the eastern coastal areas of China, including the Beijing-Shanghai Corridor. Considering that air transport below 400 kilometers along the HSR route has basically withdrawn from the competition with HSR, the data provided by Beijing-Shanghai Corridor is insufficient to analyze the relationship between delay and distance. Shanghai-Hongkong Corridor is included so that the route distance can be extended to about 2,000 kilometers in the north-south direction along the eastern coast, involving 72 routes and hundreds of thousands of flights throughout the year (excluding routes with annual flights of less than 365 and those involving Hongkong, because flights between Hongkong and mainland China are regional routes, which hold higher priorities in airport support than general domestic routes). Data period is 2017.08.13-2018.08.12 and descriptive statistics are shown in Table 1.

Table 1. OTP and Delayed Time in Beijing-Shanghai and Shanghai-Hongkong Corridors

Variable	Mean	Media	Max.	Min.	Std. Dev.	Skewness	Kurtosis
DOTP	40.82222	38.55	86.59	1.44	16.11742	0.68712	3.84101
AOTP	75.79083	77.43	94.81	1.44	13.26829	-3.2305	17.6987
ADDT	39.88889	37	219	18	23.37361	6.425303	49.50136
AADT	52.66667	50.5	205	24	21.42527	4.998021	36.77241

As shown in Table 1, the mean value of DOTP (40.82%) is less than that of AOTP (75.79%). The difference between them reached 34.97% (strikingly similar to the result in previous analysis of Beijing-Shanghai Corridor) . The standard deviation of DOTP (16.12%) is larger than that of AOTP (13.27%), which means that the departure delays fluctuate even more. The reason why AOTP is larger in mean value and smaller in standard deviation may be that all parties, including passengers, airlines and air authorities, pay more attention to the arrival OTP. Also, airlines hope to keep AOTP relatively concentrated at an acceptable level by adjusting air speed and setting buffer time. The mean value of ADDT (39.89 min) is less than that of AADT (52.66 min). The standard deviation between them is very close, with ADDT slightly higher. These similar results from different samples further prove the objectivity of the research results.

Fig. 5 (a) ~5 (d) show scatters between the 4 variables DOTP, AOTP, ADDT, AADT and flight distance respectively. Here, the horizontal axis is flight distance (km). It seems that there is no obvious correlation between the four variables and flight distance. Fig. 5 (a) shows that there is no necessary relationship between DOTP and flight distance. Fig. 5 (b), 5 (c), 5 (d) illustrate that AOTP, ADDT and AADT at different flight distances fluctuate near their mean value respectively and there is no indication of impact of flight distance on them.

This can be explained theoretically to some extent. The first is that there may be no necessary connection between delay and distance, or that distance is not the main factor affecting flight delay. Especially, departure delay and flight distance should not be related. Even if there is a correlation, it is also the relationship between arrival delay and distance. This is because there are few delays in the cruise phase of flight. Technical failures, weather, air traffic control etc. cause delays mostly in the phase of ground before departure or in the vicinity of the destination airport before arrival. Obviously, these factors have nothing to do with flight distance. The second is that there may be some relationship between arrival delay and flight distance. Theoretically, the longer the distance, the more likely it is to reduce the arrival delay by increasing the flight speed; the shorter the distance, the more difficult it is to reduce the delay by adjusting the flight speed. But nowadays, airlines usually set buffer time, which blurs the relationship between arrival delay and flight distance.

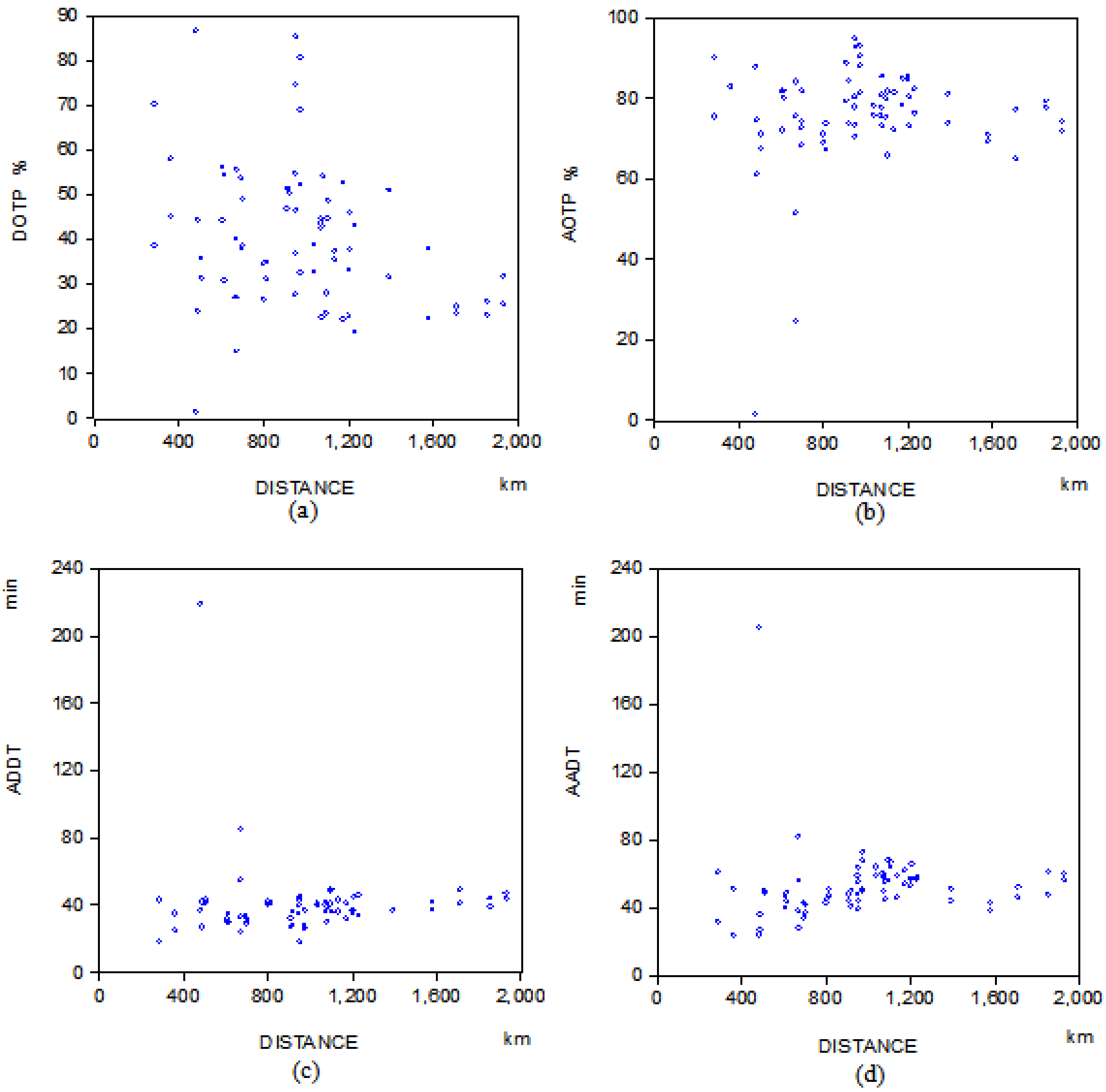


Fig. 5. Relationship between Delay and Flight Distance

V. Conclusion

China is taking a series of measures to improve on-time performance. It is a prerequisite for China to understand the characteristics of flight delays accurately before they can take correct and effective measures. This study shows that the definition of flight delay in China has undergone an evolutionary process. Fortunately, the new definition of flight delay is basically consistent with international practices, also more consistent with passenger perceptions, which makes the delay statistics comparable internationally. As far as the characteristics of flight delays are concerned, industry-level research finds that OTP of airports is always better than that of airlines. This means that airports have no incentives to pay additional costs to further improve their OTP. Consequently, air authorities either have to accept lower OTP of airlines or set higher OTP targets for airports. Meanwhile, route-level analysis shows that arrival OTP of airlines is better than that of departure OTP, but in terms of the average delayed time, the opposite is true. Further research on the distribution of the duration of delays shows that, whether arrival or departure flight, delays within 30 minutes rank the highest proportion. This implies that airlines can improve their OTP effectively by adding just a short buffer time. Finally, there is no necessary connection between delay and flight distance.

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