

# The Study on Dispatch Reliability Prediction Model of Civil Aircraft

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**Abstract:** Dispatch reliability is the key parameters to reflect the overall reliability of civil aircraft, and it is also the important technical parameters needs to be considered in the original design of civil aircraft. According to the actual delay rate data of airlines, combined with the relationship between delay rate and dispatch reliability, from the perspective of civil aircraft design, author firstly puts forward that seven design parameters of the aircraft design phase, the design parameters consist of five main parameters and two auxiliary parameters, and then this paper establishes a mathematical relationship between dispatch reliability and aircraft original design parameters, the dispatch reliability of civil aircraft was predicted, prediction model is reasonable and has higher precision accuracy, it laid the theoretical basis and data support for dispatch reliability prediction of our country civil aircraft, meanwhile the prediction model of dispatch reliability can provide reference data for the structure design of civil aircraft.

**Keywords:** Civil aircraft, design parameter, dispatch reliability, reliability.

## 1. INTRODUCTION

Dispatch reliability is the only important parameters to characterize the civil aircraft dispatch reliability, and is an important parameter to characterize the whole machine reliability of civil aircraft. Dispatch reliability directly affects the aircraft itself inherent reliability and route operational reliability. Aircraft dispatch reliability is higher, non-scheduled parking time of civil aircraft is less, the day utilization rate is higher, the reliability of flight plan is higher, at the same time the punctuality of flights will be higher. Therefore, in the aircraft original design and development stage, in-depth analysis, accurate and reliable prediction of dispatch reliability is conducted and adequate model validation is made.

Dispatch reliability is a comprehensive parameters evaluating the whole characteristic of civil aircraft, at the same time, the civil aviation transportation is a collection of airline, airport, air traffic control. Three parts must have a collaborated operation. Therefore, the consideration factors of analysis and verification about dispatch reliability is very complex. The consideration factors contain the aircraft's own technical factors, air traffic control operation environment, airport security operation, airlines management. On the one hand, dispatch reliability is affected by its aircraft structure design to a large extent; On the other hand, dispatch reliability needs to combine many non-technical factors such as actual operation environment, maintenance and security conditions.

At present the research on the dispatch reliability of civil aircraft just stay in reliability statistics report of airlines or statistics value about regular operating data in our country [1], in the civil aircraft design stage, we don't have formed to the statistics and evaluation method of dispatch reliability, so we don't have combined the dispatch reliability with aircraft original concept design.

Therefore, in the civil aircraft design stage, we shall predict the dispatch reliability level of civil aircraft during the operational phase through the structural design factors, and to determine aircraft design factors affecting flight dispatch based on the expected process and results, to adjust and improve the design method and to increase the aircraft dispatch reliability level, ensure that the economic and commercial value of civil aircraft [2].

## 2. DATA ACQUISITION

### 2.1. Definition of Dispatch Reliability

Dispatch reliability: the flight delays or cancellations caused by non-mechanical failure causes (technical reason) is divided by all the flight numbers, it is a percentage. Sometimes it referred to as the attendance reliability. In the numerical value, dispatch reliability = 1 - delays and cancellations rate.

Delays and cancellations rate is during the specified operating hours (or specified cumulative operating landing number), delays and cancellations due to technical reasons is divided by the total the number of operating flights landing. Technical delays and cancellations rate is due to mechanical failure caused by the aircraft itself, it is also known as the ground interrupt rate (ground abnormal rate, aircraft failure technical reasons).

Delays and cancellations rate formula is:

Delays and cancellations rate (ground interrupt rate)

$$= \frac{\text{delay numbers} + \text{cancel numbers}}{\text{business landing numbers}} \times 100\% \quad (1)$$

$$= \frac{\text{ground interrupt numbers}}{\text{business landing numbers}} \times 100\% \quad (2)$$

Finally, dispatch reliability (Dispatch Reliability, DR) formula can be written as:

Dispatch reliability (attendance reliability)

= 1 - ground interrupt rate (3)

$$= 1 - \frac{\text{delay numbers} + \text{cancel numbers}}{\text{business landing numbers}} \times 100\% \quad (4)$$

### 2.2. Data Collection

Due to the delay and cancellation rate dispatch reliability numerically exists corresponding relationship. So this paper firstly make a technical investigation on the maintenance engineering department and operational control ministry of domestic airline.

According to the airline's main operational production practices and maintenance reliability management programs, four kinds of short mainstream aircrafts are identified as collection objects, respectively, B737-800, A320, E190, MA60 the reliability data about the four kinds of different short-range models in four different domestic airlines is collected. Airline's annual reliability analysis report contains statistical delay rate data involved ATA subsystem chapters. Delay cancellation rate data are reliable statistics of airlines, it is the actual operating data, the airline's maintenance engineering department is responsible for statistical summary, the aim is monitoring fleet reliability, it is for real-time fleet reliability data trend analysis.

## 3. DATA PROCESSING AND ANALYSIS

### 3.1. Original Design Parameters

In order to analyze delays and cancellations rate statistically, to establish mathematical relationship between the practical operation data (delays and cancellations rate) and the aircraft itself design parameters. According to the

design concept of civil aircraft, the original design parameters were classified, it is divided into five main parameters and two auxiliary parameter, the specific parameters were seen in Table 1 [3].

The five main design parameters mainly cover the basic technical parameters of civil aircraft, including the maximum take-off weight, net thrust, flight time, cruising speed, passenger seats; the two auxiliary design parameters are involved into ratio, contain the ratio of the maximum take-off weight to flight time, the ratio of the passenger seats to flight time.

Then the design parameters of four types of collection aircraft were defined, the specific value of 7 design parameters about four kinds of plane models were obtained. The 7 design parameters were a fixed value of statistical models, the design parameters of B737-800 model as an example, see Table 2.

### 3.2. Correlation Analysis

The correlation analysis between actual delay rate statistics data of each ATA section and 7 design parameters was conducted, we can conclude that the correlation degree between each ATA section and which design parameters is highest, then each ATA section and related factors were fitted, prediction model formula between delay rate of each ATA section and certain related design factors was obtained. Correlation analysis of each ATA section, see Table 3.

Through correlation analysis, we can draw that the correlation degree between each ATA section and which related factors is maximum, the correlation coefficient r is larger, the greater the correlation degree, delay rate is identified as the dependent variable, design parameters is identified as the independent variable, we can Show that the mathematical relationship between the delays rate and design parameters is closely, the established mathematical expressions were more reliable and accurate. The largest correlation coefficient is 0.976, it can explain that the correlation between the fire prevention system as twenty-sixth chapter and the passengers' number is largest [4].

The subsystem of maximum correlation is ATA26 fire protection system, ATA35 oxygen system, and ATA80 engine, the correlation coefficients were 0.976, -0.963, -0.949. The correlation coefficients of most subsystem are above 0.5, it shows that the correlation between the actual delay rate value of most subsystem and design parameter is

Table 1. The original design parameters of aircraft.

Classification	Parameters	Abbreviation	Unit
Main design parameters	Maximum available takeoff weight	TOW	KG
	Passengers seat	PS	-
	Net thrust	NTH	KN
	Flight time	FT	HR
	Cruise speed	CS	KTS
Auxiliary design parameters	Maximum takeoff weight/flight time	TOW/FT	KG/HR
	Passengers number/flight time	PS/FT	HR <sup>-1</sup>

obvious, the correlation degree is high. Only the minimum correlation coefficient of automatic flight system is -0.163 [5].

**Table 2. B737-800 design parameters.**

Maximum takeoff weight (kg)	75978
Passengers seat	160
Flight time (hr)	6.5
Net thrust (kn)	234
Cruise speed (kts)	469
Maximum takeoff weight/flight time	11688.92
Passengers number/flight time	24.62

**Table 3. Correlation analysis of ATA section.**

ATA Chapter	Subsystem	Correlative Factor	Correlation Coefficient r
21	Air conditioning	FT	0.57
22	Automatic flight	PS	-0.163
23	Communication	FT	-0.62
24	Electrical power	NTH	0.73
25	Equipment	TOW	0.836
26	Fire protection	PS	0.976
27	Flight control	TOW/FT	0.706
28	Fuel	FT	-0.56
29	Hydraulic	PS/FT	-0.676
30	Anti-ice and rain	PS/FT	0.494
31	Instrument	FT	-0.572
32	Landing gear	FT	0.718
33	Lighting	TOW/FT	0.573
34	Navigation	PS/FT	-0.476
35	Oxygen	CS	-0.963
36	Pneumatic	FT	-0.779
38	Water	FT	-0.901
49	APU	CS	-0.532
52	Door	NTH	0.372
56	Window	TOW	0.483
80	Engine	CS	-0.949

**3.3. Prediction Model**

Through linear fitting method, the function between delay rate data of each ATA section and related design factors was established [6]. Through the numerical test, fitting degree is higher, it shows that the function expression is reasonable. Delay rate prediction formula of each ATA subsystem is shown in Table 4.

From Table 4 it can be found that fitting degree R2 of most subsystem is higher, correlation analysis can be seen that, the larger relevance of subsystems, the higher the fitting degree, the higher fitting degree of the three sub-systems were ATA26 fire protection systems, ATA35 oxygen system, ATA80 engine, fitting degree was 0.9537, 0.9281, 0.9015 [7, 8].

By fitting formula listed in Table 4, the relationship between delay rate and related design factors of each ATA subsystem can be predicted, thereby the delay rate predicted value were obtained. it can pave the way for the next model validation [9, 10].

**4. EXAMPLE VERIFICATION**

In order to verify the rationality and accuracy of the prediction rate model, based on the 7 design parameters of mainstream models of B737-800 aircraft, we can predict delay rate, we compare the unity between delay rate prediction value with the actual value, Thus we can draw the whole dispatch reliability.

Through the comparison between the actual value and the predicted value of B737-800 delay rate data, from Table 5 it is shown that the delay rate predicted data of various subsystems is basically close to the actual delay rate, because the dispatch reliability=1-ground interrupt rate=1-delay rate, it can draw the relative error between prediction value of the dispatch reliability and the actual value is small, the prediction method about the whole dispatch reliability through the relationship between the delay rate of ATA subsystem and design parameters is feasible, prediction value of dispatch reliability is accurate.

**CONCLUSION**

According to several main design factors of civil aircraft affecting dispatch reliability, by the actual sample statistics data, it makes a prediction and test on the dispatch reliability using linear regression method, the actual operation data of airline aircraft with main design parameters were effectively combined, the correlation and function relation were found out among them, the design parameters are explanatory variables, delay rate are explained variable. The quantitative relationship between delay rate data and the design parameters was established. Because of delay rate and dispatch reliability have a certain relationship, Dispatch reliability and design parameters have also the same linear relation. The linear regression prediction model of delay rate was constructed. The delay rate was predicted to get the dispatch reliability of certain aircraft, it can put a theory basis for the next step to distribute dispatch reliability.

Finally on the basis of the B738 validation instance, through statistical correlation test it is shown that, the obtained prediction model is correct, the prediction model has certain scientific value and the validity, The research results provide a scientific and reasonable method for the actual dispatch reliability prediction. In the stage of aircraft original design, we can adjust design parameters in order to improve the dispatch reliability, reduce the aircraft delay rate.

**Table 4. The prediction formula of section ATA delay rate.**

ATA Chapter	Subsystem	Delay Rate Prediction Formula (DR)	Correlative Factor	Fitting R2
21	Air conditioning	DR=0.0369(FT)-0.0469	FT	0.3252
22	Automatic flight	DR=0.0005(PS)+0.0296	PS	0.8933
23	Communication	DR=-0.0108(FT)+0.0768	FT	0.3845
24	Electrical power	DR=0.0004(NTH)+0.0789	NTH	0.5343
25	Equipment	DR=1 E-06(TOW)-0.0208	TOW	0.699
26	Fire protection	DR=0.0014(PS)-0.0784	PS	0.9537
27	Flight control	DR=2 E-05(TOW/FT)+0.0049	TOW/FT	0.4996
28	Fuel	DR=-0.0182(FT)+0.1852	FT	0.3136
29	Hydraulic	DR=-0.0073(PS/FT)+0.3192	PS/FT	0.4575
30	Anti-ice and rain	DR=0.0043(PS/FT)+0.0185	PS/FT	0.2449
31	Instrument	DR=-0.0274(FT)+0.2513	FT	0.3282
32	Landing gear	DR=0.0895(FT)-0.2244	FT	0.5162
33	Lighting	DR=4 E-06(TOW/FT)-0.0164	TOW/FT	0.3286
34	Navigation	DR=-0.0036(PS/FT)+0.4176	PS/FT	0.2272
35	Oxygen	DR=-0.0002(CS)+0.1196	CS	0.9281
36	Pneumatic	DR=-0.0486(FT)+0.3267	FT	0.608
38	Water	DR=-0.0216(FT)+0.1386	FT	0.8127
49	APU	DR=-0.0002(CS)+0.1774	CS	0.2834
52	Door	DR=0.0002(NTH)+0.0007	NTH	0.1391
56	Window	DR=1 E-06(TOW)-0.0174	TOW	0.2335
80	Engine	DR=-0.0018(CS)+1.2962	CS	0.9015

**Table 5. The contrast between the actual value and predicted value of delay rate.**

ATA Chapter	Subsystem	Prediction Value	Actual Value
21	Air conditioning	0.1930	0.2489
22	Automatic flight	0.1096	0.1244
23	Communication	0.0066	0.0415
24	Electrical power	0.1725	0.2074
25	Equipment	0.0552	0.0830
26	Fire protection	0.1456	0.1659
27	Flight control	0.2387	0.1244
28	Fuel	0.0669	0.0415
29	Hydraulic	0.1395	0.1244
30	Anti-ice and rain	0.1243	0.1659
31	Instrument	0.0732	0.1244
32	Landing gear	0.3574	0.4563
33	Lighting	0.0304	0.0415
34	Navigation	0.3290	0.2904
35	Oxygen	0.0258	0.0415
36	Pneumatic	0.0108	0.0830

(Table 5) contd.....

ATA Chapter	Subsystem	Prediction Value	Actual Value
38	Water	-0.0018	0.0000
49	APU	0.0836	0.1244
52	Door	0.0475	0.0830
56	Window	0.0586	0.1244
80	Engine	0.4520	0.5392
Total delay rate		2.7185	2.9450
Dispatch reliability		97.282	97.055
Error		0.23%	

**CONFLICT OF INTEREST**

The authors confirm that this article content has no conflict of interest.

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