

Research on Estimation of Flight Test Development Cost for Commercial Aircraft Projects

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Keywords: Commercial aircraft, Flight test, Development cost, Model

Abstract: Flight test is an indispensable part in the development of commercial aircraft projects. The cost of flight test development is directly related to the economic feasibility of the project. How to accurately estimate the flight test development costs is an important factor related to the success of the project. This article first analyzes the composition of flight test development costs and common estimation methods, and based on this, draws on the DAPCA IV model to establish a model suitable for domestic commercial aircraft model development flight test cost estimation.

1. Introduction

Flight test is a process of scientific research and product test under real flight conditions [1], and it is an important content in the process of aircraft development. It has the characteristics of real test environment and test results, high risk, complicated test, tight cycle, complicated flight test management and high cost, etc. For commercial aircraft projects, economic feasibility is a necessary condition for starting the project, and flight test is an important part of the project. Whether the flight test cost can be more accurately estimated in the project feasibility demonstration will affect the project's economic feasibility has a huge impact.

Compared to military aircraft, the flight test work of commercial aircraft projects does not include pre-research, technical research, airborne equipment certification flight test, etc. The flight test of a commercial aircraft project generally includes various flight test technical preparations, the first flight, the R & D flight test, the applicant's conformity flight test, and the certification flight test carried out after the project is initiated. According to statistics, the flight test costs of commercial aircraft projects at home and abroad account for about 7% to 15% of the total project development costs. If you add the cost of demonstration flight tests and demonstration operations for project promotion, the flight test costs are much higher than this percentage.

2. Development Cost Composition

Commercial aircraft are required to have high economics. The overall plan of the aircraft determines the overall economics of the aircraft. According to the length and cost of flight tests during the development of commercial aircraft at home and abroad, the overall economic impact of the project is huge. Therefore, how to accurately estimate the flight test costs in the initial phase of model development is of vital importance for controlling the model development expenditure.

There is currently no uniform definition of the cost of commercial aircraft development and flight tests. The new technologies, marketing strategies and the number of options available to customers will affect the content and workload of the flight test, and thus the cost of the flight test. The cost of commercial aircraft development and flight test shall include all the costs of preparations for the first flight, R & D flight test, compliance flight test, certification flight test and operation flight test. The specific flight test cost includes fuel oil, test equipment, modification, and data processing. Specific fees include:

1) Flight test plan and other design costs; 2) Flight test data processing; 3) Flight test modification; 4) Flight test equipment; 5) Flight test fuel; 6) Salary of flight test personnel

(including crew and ground); 7) Insurance costs; 8) Rental of flight test venues and facilities [2].

3. Commonly Used Flight Test Cost Estimation Methods

Commercial aircraft project development cost estimation methods can be divided into two types: “top-bottom” and “bottom-up” methods, including analogy, parameter method, engineering estimation method, and trend extrapolation method. The process is shown in Figure 1.

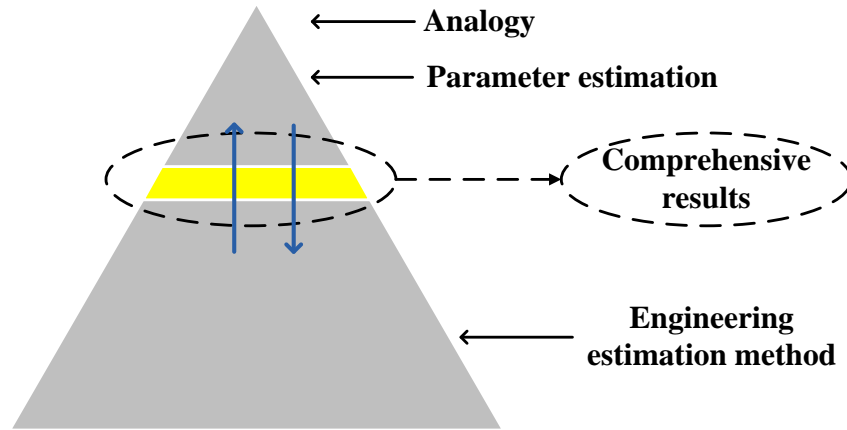


Fig.1 Comparison of Methods for Estimating Development Costs of Commercial Aircraft Projects

The use conditions and estimation accuracy of different methods are different. According to the division of commercial aircraft development phases and the characteristics of each phase, different cost estimation methods are used in different development phases, as shown in Table 1. Among them, in the project demonstration phase, the analog method and the parameter method are more applicable, and the engineering estimation method is not applicable. As the development advances to the pre-development phase of the project, the engineering estimation method starts to be more applicable, and as the development further deepens, this method will become more applicable and accurate.

Table 1 Applicable Estimation Methods At Various Phases of Commercial Aircraft Development

Cost estimation method	Scheme demonstration phase	Engineering pre-development phase	Engineering development phase		Batch production phase	Operational phase
			Early	Late		
Parameter estimation	Applicable	Partially applicable	Partially applicable	Not applicable	Not applicable	Not applicable
Engineering estimation method	Not applicable	Partially applicable	Applicable	Applicable	Applicable	Applicable
Analogy	Partially applicable	Partially applicable	Applicable	Not applicable	Not applicable	Not applicable
Trend extrapolation method	Not applicable	Partially applicable	Applicable	Applicable	Applicable	Applicable

3.1 Top-Bottom Approach

1) Analogy

The analogy is based on a comparison of similar engineering projects in the past, and draws cost estimates based on experience plus corrections. Considering that the function, layout and performance of the new project are similar to those of the successfully developed project, the cost data of the similar project can be corrected by considering the differences in configuration and time between the new and old projects, so as to obtain the new project office. The analog method is generally used in the early stage of project development. The actual cost data of new projects is very small. At this time, only one or two similar products can be used for comparison. Therefore,

the analog method is more suitable for rough estimation of project costs. It is a supplementary method as the basis for the analogy analysis of the fund estimates in the later stages of the project.

The analogy method is more accurate for the flight test cost estimation of serial development of the same type of aircraft or improvement and modification of old aircraft.

2) Parameter estimation

Parametric method cost estimation is a method of quantitative analysis based on the historical data of the model, using statistical methods, by establishing a mathematical model between the development funds and certain technical parameters such as performance and physical quantities.[3] Using this method to estimate the development expenditure usually establishes the cost estimation relationship (i.e., the function expression) based on the historical cost data of the company's existing model and the technical performance parameters, and then revises it based on the performance parameters of the new model. Using this model, it can be estimated project development cost. [4]

3.2 Bottom-Top Approach

The bottom-up method is mainly the engineering estimation method, or technical analysis method, which is the most detailed and time-consuming method of project cost estimation. The project system is mainly divided into several sub-systems according to the engineering drawings, and each sub-system is divided into several sub-systems, and it is decomposed until it cannot be decomposed. In this way, the tree structure of the project system can be obtained, which is the work of the project. Break down the structure chart, then estimate the cost of the subsystem according to each system component, compile a cost manual for the subsystem, and collect the estimated costs of each system from the bottom up, and add them up to calculate the total product cost methods.

4. Development Cost Estimation Model of Commercial Aircraft Project Flight Test Based on Dapca Iv Model

Entrusted by the U.S. military, the RAND Corporation of the United States, through the analysis of aircraft life cycle costs, proposed the first model of aircraft development and procurement costs, DAPCA I, in 1967, followed by 1971, 1976, 1987 and 1995, DAPCA II, DAPCA III, and DAPCA IV were established. DAPCA has been proven to be effective in estimating aircraft development costs.

There are differences in the management systems, technical levels, and economic systems of aircraft development in different countries, so the universality of the parameter model formulas in different countries is slightly different. This paper combines the domestic and foreign commercial aircraft and the theoretical model for estimating the development costs of transport aircraft, and draws on the DAPCA IV model to establish an estimation model for the flight test costs of domestic commercial aircraft types.

4.1 Design Costs Such as Flight Test Plans

$$C_{Design} = a_1 \cdot N_1 + a_2 \cdot N_2 \quad (1)$$

C_{Design} is the flight test design cost, N_1 is the number of flight test engineers the main work is to develop flight test outline, flight test plan, test modification design, etc. a_1 is the salary rate of flight test engineers, N_2 is the number of flight test technical personnel, a_2 is the salary rate of key technical personnel.

4.2 Flight Test Data Processing

$$C_{Test} = C_{wage} + C_{consumables} \quad (2)$$

$$C_{wage} = T(\text{Man-hours for testing and data processing}) \times \text{Man-hour rate} \quad (3)$$

$$C_{consumables} = a_{consumables} (\text{Consumption per flight}) \times N_{flight} \quad (4)$$

C_{wage} is the total man-hour cost of personnel performing testing and data procession, $C_{consumables}$

is the cost of consumables for data processing, N_{flight} is flight hours.

4.3 Flight Test Modification

$$C_{Instrument} = C_{material} + C_{manufacture} + C_{recover} + C_{calibration} \quad (5)$$

$$C_{manufacture} = a_{modification\ rate} \times T_{modification\ hours} \quad (6)$$

$$C_{recover} = 0.04 \times (C_{material} + C_{manufacture}) \quad (7)$$

$C_{material}$ is the material cost required for the flight test modification, calculated based on the number of modified test aircraft. $C_{manufacture}$ is the total man- cost of the test modification. $C_{recover}$ is the cost of restoration and modification, which is usually calculated at 4% of the cost of modification materials and labor hours.

$C_{manufacture}$ is the total man- cost of the test modification, $C_{calibration}$ is the load and equipment calibration cost.

4.4 Flight Test Equipment

$$C_{Equipment} = C_{special} + C_{self-developed} + C_{share} \quad (8)$$

$$C_{share} = a_{share} \times N_{share} \quad (9)$$

$C_{special}$ is the outsourcing fee for the special equipment of the model, which is accumulated by item. $C_{self-developed}$ is the cost of self-developed special equipment and instruments, which are accumulated by item. C_{share} is the equipment cost that should be shared by the project. a_{share} is the apportionment rate of equipment, N_{share} is the hours of use of the equipment.

4.5 Flight Test Fuel

$$C_{fuel} = a_{fuel\ price} \times a_{fuel\ consumption\ rate} \times N_{flight} \quad (10)$$

Different test missions have different fuel consumption rates. In order to estimate the fuel consumption rate, the fuel consumption rate can be obtained by selecting a typical mission profile and using the amount of fuel consumed and flight hours of the mission profile.

4.6 Salary of Flight Test Personnel (Including Crew and Ground Staff)

$$C_{flight} = C_{salary} + C_{subsidy} \quad (11)$$

C_{salary} is the salary of flight test personnel, including test pilots, flight test engineer, and ground staff. It is calculated annually according to the number of personnel required for the project and the project cycle. $C_{subsidy}$ is a flight subsidy.

$$C_{subsidy} = C_{polit} + C_{flight\ test\ engineer} + C_{ground\ staff} \quad (12)$$

C_{polit} is a subsidy for test pilots, $C_{flight\ test\ engineer}$ is a subsidy for flight test engineer, $C_{ground\ staff}$ is a subsidy for ground staff.

$$C_{polit} = N_{polit} \times (a_{low-p} \times N_{flight\ hour\ low} + a_{med-p} \times N_{flight\ hour\ med} + a_{high-p} \times N_{flight\ hour\ high}) \quad (13)$$

$$C_{flight\ test\ engineer} = N_{engineer} \times (a_{low-e} \times N_{flight\ hour\ low} + a_{med-e} \times N_{flight\ hour\ med} + a_{high-e} \times N_{flight\ hour\ high}) \quad (14)$$

N_{polit} is the number of test pilots per flight. $N_{engineer}$ is the number of flight test engineer per flight. a_{low-p} and a_{low-e} are the subsidy rates for test pilots and test engineers in low-risk subjects. a_{med-p} and a_{med-e} are the subsidy rates for test pilots and test engineers in medium-risk subjects. a_{high-p} and a_{high-e} are the subsidy rates for test pilots and test engineers in higher-risk subjects. $N_{flight\ hour\ low}$, $N_{flight\ hour\ med}$ and $N_{flight\ hour\ high}$ are the hours of low, medium, and high risk flights.

$$C_{ground\ staff} = a_{ground\ staff} \times N_{ground\ staff} \times N_{day-g} \quad (15)$$

$a_{ground\ staff}$ is the ground staff subsidy rate. $N_{ground\ staff}$ is the number of ground staff. N_{ady-g} is the number of flight days.

4.7 Insurance Costs

$C_{insurance}$ is the insurance cost for flight test. The flight test insurance cost is calculated based on the number of flights, usually calculated at 0.1 % of the catalog price of the aircraft.

4.8 Rental of Flight Test Venues and Facilities

C_{rent} includes the airport's various services, the rental of ground equipment, and the use of navigation facilities, which are generally calculated according to the type of aircraft and the number of flights. It is usually divided into 5 levels according to the maximum take-off weight specified on the airworthiness certificate.

5. Conclusion

This paper analyzes the requirements of flight test costs during the development of commercial aircraft projects, analyzes and researches several methods for estimating the flight test development costs of current commercial aircraft projects, and proposes a model for estimating the flight test costs of commercial aircraft based on the DAPCA IV model. Tested by actual projects, the model has a high degree of confidence. The regression analysis of this model combined with various domestic and foreign commercial aircraft development databases can be used to estimate the cost of domestic commercial aircraft model flight test.

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