Research on the Experimental Cost Estimation Model in the Civil Aircraft Development Phase

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Abstract: With the increasing maturity of domestic civil aircraft technology and the entry of domestically produced civil aircraft into the market, civil aircraft enterprises are gradually strengthening their awareness and capabilities in cost control to achieve higher profit margins by controlling aircraft costs. For aircraft manufacturers, controlling development costs during the aircraft development phase is crucial. Test costs are an important component of development costs, and there is a large number and variety of tests during the civil aircraft development phase. Therefore, it is essential to establish a universal test cost estimation model to meet the manufacturer's need for efficient and accurate control of test costs. This article introduces a test cost estimation model for the civil aircraft development phase, considering nine types of costs, including labor costs, equipment costs, and fuel costs. The rationality of this model is validated through research, calculations, and result comparisons.

Keywords: Civil aircraft, development phase, experiment, cost estimation

1 Introduction

In the development process of civilian aircraft, planning and implementation of test projects are essential aspects of the development work[1]. The funds for test projects are also an important component of model development costs. The basis for controlling test-related expenses is to understand the cost situation of the laboratory and test projects. However, there is currently a gap in models that can calculate test costs. This article will introduce and validate such a model and the verification process.

2 The Model

2.1 Model introduction

By studying other materials[2][3][4] and combining them with the testing scenarios in the stages of developing civilian aircraft，the costs of Experiment in civil aircraft development phase consist of nine components: labor costs, test equipment usage fees, fuel and power costs, specialized fees, transaction fees, material costs, outsourcing fees, management fees, and taxes.

2.1.1 Estimation of Labor Costs

Labor costs refer to the total expenses associated with all labor involved in the testing process, including the costs incurred for test preparation, test implementation, and personnel input for test completion. When calculating labor costs, each item should be calculated individually in the testing process, as shown in Table 1. This cost calculation method is similar to the job costing method[5]. The formula for calculating labor costs is provided in Formula 1.

$$C_L = \sum \left(n_L \times t_L \times a_L \right) \tag{1}$$

In the formula，

C_L ——Labor Cost, yuan

n_L ——Total Number of Labor Inputs, people

t_L ——Average Working Hours per Person, hours per person

a_L ——Labor Rate, yuan per hour

Table 1: Template for Labor Cost Estimation

Serial No.	Test Process	n_L	t_L	a_L	Total
1	Test Preparation				
1.1	Test Outline				
1.1.1	Prepare Test Outline				
1.1.2	Approve Test Outline				
1.2	Test Equipment				
1.2.1	Test Equipment Debugging				
1.3	Test Items				
1.3.1	Test Fixture Design				
1.3.2	Test Item Mounting				
2	Test Implementation				
2.1	Pre-Test				
2.1.1	Debugging				
2.1.2	Alignment				
2.2	Formal Test				
2.2.1	Test Item Mounting				
2.2.2	Test Process				
2.2.3	Installation and Removal of Test Items				
3	Test Completion				
3.1	Record Test Log				
3.2	Test Data Processing				
3.3	Prepare Test Report				
3.4	Prepare Test Analysis Report				
	Total				

The labor cost rate is based on the annual labor cost rate standard published by the company. If the project spans multiple years, it should be calculated based on the annual labor cost increase provided by the Finance Department, combined with the estimated proportion of labor hours for each year.

2.1.2 Equipment Usage Fee Calculation

The equipment usage fee refers to the expenses incurred when using the experimental equipment. When calculating the equipment usage fee, the fee for each piece of equipment should be calculated individually and then summed up. The template can be found in Table 2. The usage fee for each piece of equipment is equal to the equipment usage rate multiplied by the equipment usage time.

Table 2: Equipment Usage Fee Estimation Template

Serial No.	Equipment Name	a_E	Equipment Usage Time (h)	Total
1	Equipment 1			
2	Equipment 2			
3	Equipment 3			
	Total			

In this table, the equipment usage rate should be calculated based on equipment acquisition costs, the available equipment usage hours, and annual maintenance and calibration expenses. When the annual maintenance and calibration expenses as a percentage of equipment acquisition costs exceed 10%, the equipment usage rate calculation formula can be found in Formula 2.

$$a_E = (P/H) \times (1 + M/P) \tag{2}$$

In the formula:

   a_E ——Equipment Usage Rate, yuan per hour

   P ——Equipment Acquisition Costs, yuan

   H ——Equipment Available Usage Hours, hours

   M ——Annual Maintenance and Calibration Expenses, yuan

When the annual maintenance and calibration expenses as a percentage of equipment acquisition costs are less than 10%, the equipment usage rate calculation formula can be found in Formula 3.

$$a_E = (P/H) \times 1.1 \tag{3}$$

In the formula:

   a_E ——Equipment Usage Rate, yuan per hour

   P ——Equipment Acquisition Costs, yuan

   H ——Equipment Available Usage Hours, hours

2.1.3 Fuel and Power Cost Estimation

Fuel and power cost refers to the total expenses incurred for water, electricity, gas, fuel, and other costs during the operation of test equipment. Each fuel cost is calculated by multiplying the fuel price by the consumption volume. If standardized prices are available for the fuel used, such as water, electricity, natural gas, gasoline, etc., they should be used for calculation. For other fuels like methane or propane, the laboratory purchase price or average market price can be used for calculation. The formula for fuel and power cost calculation is found in Formula 4.

$$C_F = \sum (a_F \times n_F) \tag{4}$$

In the formula:

C_F ——Fuel and Power Cost, yuan

a_F ——Fuel Price, CNY per liter, per kilowatt-hour, per bottle, etc.

n_F ——Fuel Consumption Volume, liters, kilowatt-hours, bottles, etc.

2.1.4 Specialized Fee Estimation

Specialized fees refer to the costs that must be incurred in a project, including specialized tool and software fees, technology transfer fees, and intellectual property usage fees.

2.1.4.1 Specialized Tool and Software Fee Estimation

Specialized tool and software fees refer to the costs of using computer programs (including software upgrades) required to complete the project, excluding common office software. The specialized tool and software fee is equal to the software purchase price (including upgrades) multiplied by the apportionment ratio. The apportionment ratio is calculated based on the project duration's share of the current version's lifespan. The formula for specialized tool and software fee calculation can be found in Formula 5.

$$C_s = \sum S \times (H_P / H_s) \tag{5}$$

In the formula:

C_s ——Specialized Tool and Software Fee, yuan

S ——Software Purchase Price (including upgrades), yuan

H_P ——Project Duration, hours

H_s ——Current Software Version Lifespan, hours

2.1.4.2 Intellectual Property Usage Fee Estimation

Intellectual property usage fee refers to the fees payable to intellectual property rights holders in accordance with relevant national laws and regulations. The intellectual property usage fee is equal to the intellectual property service fee multiplied by the apportionment ratio, which is determined by the intellectual property rights holder based on the project's circumstances. The formula for intellectual property usage fee calculation can be found in Formula 6.

$$C_I = \sum K \times b \tag{6}$$

In the formula:

C_I ——Intellectual Property Usage Fee, yuan

K ——Intellectual Property Service Fee, yuan

b ——Apportionment Ratio

2.1.5 Expense Calculation

Expenses include conference fees, travel expenses, accommodation costs, meal subsidies, and expert consultation fees.

2.1.5.1 Conference Fee Calculation

Conference fees mainly refer to the expenses incurred when renting venues outside the company for meetings, including accommodation costs, meal expenses, venue rental, transportation costs, materials, and miscellaneous fees. Transportation costs primarily include expenses related to transporting conference delegates. The conference fee is equal to the quantity multiplied by the conference fee rate. The quantity is measured in person-days, and the conference fee rate standard is based on the company's reimbursement standards.

2.1.5.2 Travel Expense Calculation

Travel expenses are expenses incurred during the project for experiments, scientific investigations, business research, and work-related exchanges, both domestically and internationally. In external business projects, it mainly refers to transportation expenses, including airfare, train tickets, and high-speed rail tickets. The travel expense is equal to the quantity multiplied by the travel expense rate. The quantity is measured in person-trips, and each one-way trip counts as one person-trip. For example, if 2 people take a flight for a business trip once, the quantity should be 4 person-trips. The travel expense rate standard is based on the prices from reputable ticket-selling platforms.

2.1.5.3 Accommodation Cost Calculation

Accommodation costs refer to the expenses incurred for accommodation during experiments, scientific investigations, business research, and work-related exchanges. The accommodation cost is equal to the quantity multiplied by the accommodation cost rate. The quantity is measured in person-nights, and the accommodation cost rate standard is based on the company's reimbursement standards.

2.1.5.4 Meal Subsidy Calculation

Meal subsidies are expenses incurred during the project for meals and indoor transportation, such as transportation within the workplace. Meal subsidies are calculated by multiplying the quantity by the meal subsidy rate. The quantity is measured in person-days, and the meal subsidy rate standard is based on the company's reimbursement standards.

2.1.5.5 Expert Consultation Fee Calculation

Expert consultation fees refer to one-time payments to experts for their evaluation and consultation services during the project. The expert consultation fee is equal to the quantity multiplied by the expert consultation fee rate. The quantity is measured in person-times. The expert consultation fee rate standard is based on the company's reimbursement standards.

2.1.6 Material Cost Calculation

Material costs are the total expenses incurred for materials during the implementation of experiments. Each material cost is calculated by multiplying the material unit price by the material consumption quantity. The material unit price can be based on the laboratory's procurement price or the average market price.

2.1.7 Outsourcing Cost Calculation

Outsourcing costs refer to the expenses incurred by the Aviation Institute when external units are required to carry out research, design, processing, testing, software evaluation, experiments, etc., due to limitations in their own technology, processes, and equipment during the project.

For cases where the contracting party is an external company, the outsourcing cost is equal to the total of various outsourcing contract costs. If the outsourcing project has not yet occurred, the maximum predicted cost should be used.

For cases where the contracting party is an internal company unit, the outsourcing cost calculation method follows the company's internal unit settlement method.

2.1.8 Management Fee Calculation

Management fees refer to the management-related expenses incurred during the project.

For cases where the contracting party is an external company, the management fee is calculated as a percentage of the total of equipment usage fees, fuel and power fees, labor fees, special fees, transaction fees, material fees, outsourcing fees, and tax fees. This percentage is determined by the company based on its own circumstances.

For cases where the contracting party is an internal company unit, the management fee calculation method follows the company's internal unit settlement method.

2.1.9 Tax Fee Calculation

Tax fees for external business projects include value-added tax, education surtax, local education surtax, and urban construction tax. The tax rates are based on the tax rates in effect at the time of contract signing.

2.2 Model verification

Due to the large number and variety of tests in the development phase of civil aircraft, and the sensitivity of test data among peer companies, which is not easily accessible, this article selects four typical tests that use industry-standard methods as the model for estimation and validation. These tests include combustion tests, strength tests, non-destructive testing, and

lighting tests. The selection is based on two points: first, these four typical tests all use industry-standard methods, and testing and inspection institutions with legitimate qualifications can provide similar testing services; second, through inquiries and consultations, it is relatively easy to obtain market quotations for these four typical tests.

Through on-site investigations of the combustion test lab, strength test lab, non-destructive testing lab, and lighting test lab of a certain civil aviation company, the daily operating costs of these labs are collected and input into the model for calculation. The calculated results are then compared with market quotation data for the same types of tests to validate the model's rationality.

2.2.1 Implementation Steps

2.2.1.1 On-site Investigation

Visit the combustion test lab, strength test lab, non-destructive testing lab, and lighting test lab of a certain civil aviation company to conduct on-site inspections of the lab's facilities, daily management, pre-test preparations, implementation processes, post-test disposal, and routine maintenance.

2.2.1.2 Data Integration

1) Summarize the investigation findings and organize the operational information and relevant data of various types of labs;

2) Review data related to the same types of tests and integrate market quotation information.

2.2.1.3 Data Calculation and Model Validation

Input the test data obtained from the investigation into the model, compare it with market quotation data for the same types of tests, analyze the differences, and adjust the model based on deviations.

2.2.2 Validation Conclusion

Using this model, cost estimates were carried out for four types of tests: combustion, strength, lighting, and non-destructive testing, resulting in a total of 28 cost estimates. The calculated results are listed in Table 3. Due to the sensitivity of cost data, the data in the table has been blurred for confidentiality.

Table 3: Comparison of Calculated Results with Market Prices

Serial No.	Experiment Category	Experiment Name	Calculated Cost (CNY)	Market Price (CNY)
1	Combustion Test	Flame Retardant Test	500	1000
2		Seat Cushion Flammability Test	2000	6500
3		Cargo Liner Flame Penetration Resistance Test	3000	8000
4		Cabin Material Heat Release Rate Test	2000	6500
5		Interior Material Smoke Density Test	2000	3500

Serial No.	Experiment Category	Experiment Name	Calculated Cost (CNY)	Market Price (CNY)
6		Thermal-Acoustic Material Flammability and Flame Spread Test	2000	7000
7		Thermal-Acoustic Material Anti-Burn-Through Test	3000	10000
8		Non-Metallic Material Combustion Toxic Gas Emission Test	2000	4500
9		Standard Static Test (Environmental Chamber)	100	100-300
10		Standard Static Test	50	
11	Strength Test	Standard Fatigue Test (Environmental Chamber)	300	2000-3000
12		Standard Fatigue Test	200	
13		Bearing Test (Fatigue)	6000	10000
14		Bearing Test	600	
15		Luminous Flux Test	6000	10000
16		Brightness Test	6000	10000
17	Lighting Test	Light Distribution Curve Test	6000	10000
18		Color Temperature Test	6000	10000
19		Color Coordinate Test	6000	10000
20		Illuminance Test	6000	10000
21		Metal Conventional Eddy Current Test	6000	7900
22		Metal Low-Frequency Eddy Current Test	6000	7900
23		Metal Conventional Ultrasonic Test	6000	7900
24		Metal Phased Array Ultrasonic Test	6000	7900
25	Non-destructive Testing	Composite Material Conventional Ultrasonic Test	7000	10000
26		Composite Material C-Scan Ultrasonic Test	6000	10000
27		Metal Structure Industrial Endoscope Visual Inspection Test	5000	10000
28		Composite Material Structure Industrial Endoscope Visual Inspection Test	5000	10000

The validation results show that the cost values calculated using this model are all lower than the market prices, aligning with market trends. Therefore, it can be concluded that the calculation methods used in this model are reasonable.

3 Conclusion

The above is the experimental Cost Estimation Model in the Civil Aircraft Development Phase. This model introduces the methods for calculating expenses in nine aspects: labor costs, test equipment usage fees, fuel and power fees, special fees, transaction fees, material fees, outsourcing fees, management fees, and tax fees. It provides a comprehensive consideration of the entire experiment project's cost elements. Selecting combustion tests, strength tests, lighting tests, and non-destructive tests as validation objects, we input the data obtained from the survey into the model for calculation. By comparing the calculated results with market

quotations, we find that they conform to market trends. Therefore, this validates the reasonableness of the model.

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