Research on Civil Aircraft Direct Maintenance Cost Analysis and Optimization Based on Data Mining

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Abstract. Civil aircraft maintenance cost is an important indicator to measure the maintainability and economy of civil aircraft, and it accounts for a considerable proportion of aircraft operating costs. Data mining technology can unearth potentially high-value data from massive aircraft operating data. In this paper, aiming at the problem that there are very few actual aircraft maintenance data that can be effectively used in the development stage of civil aircraft, the research on the direct maintenance cost analysis and optimization method of civil aircraft based on data mining is carried out. The theoretical basis of direct maintenance cost analysis based on data mining is studied, the factors affecting the direct maintenance cost of civil aircraft are analyzed based on data mining, and the DMC analysis method is established. On the basis of the above research, the direct maintenance cost analysis model of civil aircraft was established and optimized to achieve the goal of reducing direct maintenance costs. It is of great significance for reducing aircraft life cycle costs and improving aircraft market competitiveness.

Keywords: Data Mining, Civil Aircraft, Direct Maintenance Cost

1. Introduction
Civil aircraft maintenance cost is the summation of direct maintenance cost (DMC) and indirect maintenance cost. The DMC is the direct cost of man hours and materials in the process of maintenance [1]. It consists of airframe maintenance cost and power plant maintenance cost, in which, both airframe maintenance cost and power plant maintenance cost can also include labor hour cost and material cost respectively.

DMC, part of maintenance cost, has a close link with the development level and maintenance design capability of the aircraft. DMC is a key component of direct operating cost. It is derived directly from the design of aircraft and is of great important parameter when measuring the maintainability and economy of civil aircraft [2]. Its amount directly influences the profit of Airline Company. There is hardly any airline company willing to buy aircraft with an exorbitant DMC.

When conducting DMC analysis, a large amount of maintenance data generated during the operation process needs to be used, and these data have a guiding role in carrying out direct aircraft maintenance cost analysis [3]. However, at present, these data and information are scarce and there is no systematic management, which poses a challenge to the timeliness, accuracy, and sharing of the
DMC analysis of civil aircraft [4-9]. Therefore, it is urgent to carry out research on data mining technology related to the DMC analysis. Extract useful information and knowledge from the data, automatically, intelligently and quickly discover the hidden dependencies in a large amount of maintenance data, and propose DMC optimization suggestions from different aspects. This paper proposes the use of data mining methods to extract useful information from historical maintenance data for DMC analysis of civil aircraft, and lays a foundation for the development of DMC optimization.

2. DMC Analysis Method for Civil Aircraft

Aircraft DMC analysis methods are established based on the statistical analysis of the maintenance data accumulated for years by the airline companies. Currently the most popularly used calculation methods in the world include the ATA, AEA and NASA 95 method. When conducting DMC analysis of civil aircraft, it must be synchronized and coordinated with aircraft design work, marketing work and customer service work. It is necessary to comprehensively plan and coordinate the DMC analysis work at each stage. The main process of direct maintenance cost analysis is shown in Figure 1.

![Diagram](image)

**Fig 1.** DMC analysis process

The aircraft level DMC analysis is based on components, and all maintenance activities of the aircraft are classified into planned maintenance tasks and unplanned maintenance tasks. The above two tasks are divided into system scheduled maintenance tasks, system unscheduled maintenance tasks and structural maintenance tasks.

2.1 System Scheduled Maintenance Tasks DMC Analysis

Scheduled maintenance includes line scheduled maintenance, scheduled check and shop maintenance task. Aircraft maintenance planning document will supply the scheduled maintenance task of system onboard equipment and components, including scheduled updating, scheduled check task and service work. The detail about the scheduled maintenance task is shown as follows Table 1.

The DMC of the Scheduled Check is shown in formula 1.

\[
DMC_{Scheduled} = \frac{R \times MH_{ON}}{T_R}
\]  

(1)

In the equation:

- \(DMC_{Scheduled}\) - Scheduled maintain DMC ($/fh)$.
- \(R\) - Maintenance man hour rate ($/h)$.
- \(MH_{ON}\) - In-situ maintenance man hour for scheduled maintenance tasks (h).
- \(T_R\) - Maintenance interval for scheduled maintenance tasks (fh).

The DMC calculation for scheduled maintenance of life limit components is shown in formula 2.
\[ DMC_{Scheduled} = \frac{R \times MH_{ON,lim} + MC}{T_F} \]  

(2)

In the equation:
- \( MH_{ON,lim} \) - The off-site maintenance man hours of the scheduled maintenance tasks of the life limit components (h).
- \( MC \) - Maintenance material costs for scheduled maintenance tasks.

### Table 1. Scheduled maintenance task classification

| Type                | Name | Definition |
|---------------------|------|------------|
| Scheduled update    | DIS  | Discard is defined as when an equipment reaches the life limit, whether it has a failure or not, it will be discarded and replaced with a new one. |
|                     | RST  | Restoration is defined as both of the labor cost and material cost of replacement and cleaning component, repair and overhauled the equipment. |
| Scheduled Check     | GVI  | General Visual Inspection is to check for obvious damage, failure and abnormal signs, while conducting a visual inspection of the internal/external installation components. Except the special instructions, GVI should be within the reachable range. |
|                     | OPC  | Operational Check is a work to find the failure, which doesn’t need quantitative requirements. |
|                     | FNC  | Function Check is defined as a qualitative check, which is used to ensure whether a function or multiple functions within the specification range or not. |
|                     | DET  | Visual Check is defined as an observation work to find the failure, which doesn’t need quantitative requirements. |
|                     | SDI  | In order to inspect the damage, failure or abnormal sign, detailed inspection is defined as a careful examination of a special project and component. |
| Service             | LUB  | In order to maintain the inherent design performance to take a lubrication task. |

#### 2.2 System Unscheduled Maintenance Tasks DMC Analysis

The DMC of unscheduled maintenance is mainly related to the mean time between unscheduled removals and no fault found rate. When a component is a consumable component, the component is directly replaced after a failure, and the DMC is labor and material costs. The DMC calculation for unscheduled maintenance of such components is as follows.

\[ DMC_{Unscheduled} = \frac{R \times 0.5 + P_L}{MTBUR} \]  

(3)

In the equation:
- \( DMC_{Unscheduled} \) - Unscheduled maintenance DMC ($/fh).
- \( P_L \) - The purchase price of the component (including off-site labor costs).
- \( MTBUR \) - mean time between unscheduled removals (fh).

When a component is non-consumable, send it for repair after it fails. According to engineering experience, the maintenance cost caused by no fault found of component is about 10% of the component, and the maintenance cost of normal repairs is about 25% of the cost of the component. The DMC calculation for unscheduled maintenance of such components is as follows.

\[ DMC_{Unscheduled} = \frac{P_L \times (25\% - 15\%NFPR)}{MTBUR} \]  

(4)

In the equation:
NFFR - No fault found rate.

2.3 Structural Maintenance Tasks DMC Analysis

Structural maintenance DMC is divided into structural scheduled maintenance DMC and structural unscheduled maintenance DMC according to maintenance tasks. The scheduled maintenance cost of the structure comes from the scheduled maintenance tasks of the structure in the aircraft MPD, and the calculation formula is as follows.

\[
DMC_{\text{Structure\_Scheduled}} = \frac{R \times \Sigma MH_{DMC} + \Sigma MC_i}{T_R}
\]  

(5)

In the equation:
- \(DMC_{\text{Structure\_scheduled}}\) - Structure scheduled DMC ($/fh).
- \(MH_{DMC}\) - The in-situ maintenance man hour required for the structural scheduled maintenance task i (h).
- \(MC_i\) - The maintenance material cost required for the structural scheduled maintenance task i ($).
- \(T_R\) - The maintenance interval of the scheduled maintenance task of the structure (fh).

According to statistical experience, structural unscheduled maintenance costs are generally a multiple of structural scheduled maintenance costs, and can be calculated as follows.

\[
DMC_{\text{Structure\_unscheduled}} = \beta \times DMC_{\text{Structure\_scheduled}}
\]  

(6)

In the equation:
- \(DMC_{\text{Structure\_unscheduled}}\) - Structure unscheduled DMC ($/fh).
- \(\beta\) - According to the statistical data of structural maintenance, it is generally 1.5-2.5.

3. Data Mining in DMC Analysis

3.1 Data Collection

The first step of DMC analysis based on data mining is to collect maintenance data during the use of aircraft. Then the data is preprocessed through the expert model, useful data is initially screened, data cleaning, data integration, data transformation are completed to form a database [10, 11]. According to the data needed in the DMC analysis, the aircraft maintenance data is divided into line maintenance, scheduled maintenance and unscheduled maintenance for collection.

The line maintenance data includes the type and date of the actual line maintenance work, the number of pre-flight/transit/post-flight inspections, the actual flight time and block time of the aircraft.

The scope of scheduled maintenance data is the scheduled maintenance content of the airline based on the main manufacturer of the civil aircraft in the maintenance plan documents, including A Check, multiple A Check, C Check, and multiple C Check. MPD task number, task interval, actual working hours, related components information and other data need to be recorded.

The scope of unscheduled maintenance data includes unscheduled maintenance work during the execution of scheduled maintenance tasks or during operation, including landing gear overhaul, APU overhaul, engine overhaul, and replacement of life limit components. The actual working hours, aviation material information, the time of use this time, the date of disassembly and assembly, and the repair cost of the maintenance task need to be collected.

3.2 Data Mining

Select appropriate algorithms to conduct in-depth mining of the aircraft maintenance data. Commonly used data mining algorithms include neural networks, support vector machines, K-means clustering, association rule algorithms, etc., to build models to generate association rules. Performed data mining on the DMC values and trends of each aircraft and fleet, and the causes of sudden changes and abnormal trends will be found, and the key factors affecting DMC will be found based on a large amount of data.
3.3 DMC Optimization Based on Data Mining

According to the results of data mining, the DMC design can be optimized to reduce DMC.

Choose maintenance intervals and maintenance tasks in reason. The rationality of the maintenance interval and the selection of maintenance tasks will directly affect the DMC. For maintenance tasks that affect safety, a reasonable maintenance interval needs to be recommended based on the failure rate data. For other maintenance tasks, the number of scheduled maintenance tasks should be minimized under the premise of ensuring safety.

Improve maintainability design and reduce maintenance man hour. For civil aircraft, the maintainability directly affects the maintenance hours of equipment or structures. Therefore, accessibility should be improved and modular design should be strengthened to reducing maintenance man hours.

Reduce failure rate to reduce unscheduled maintenance. Unscheduled maintenance account for a significant proportion of DMC. In the case of certain development costs and spare parts costs, equipment with high reliability should be selected as far as possible.

Reduce the price of aviation materials or spare parts. When selecting the equipment provided by the supplier, the main manufacturer should select materials or spare parts with favorable prices on the premise of ensuring that the functions and reliability meet the indicators to reduce the cost of unscheduled repairs.

4. Conclusions

The aircraft DMC will contribute directly to balancing the relation between aircraft safety, reliability and economic effect, and a better profit for aircraft operators. This paper studies the DMC analysis method of civil aircraft, and proposes DMC optimization through data mining, and finally proposes the optimization idea of DMC. So that DMC can meet the design index requirements and achieve market success.

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