Cost Analysis of Preventive Maintenance for Commercial Aircraft Based on System Simulation

Pu Li[a]
Shanghai Aircraft Design and Research Institute, China

Keywords: Preventive Maintenance, System Simulation, Cost Analysis.

Abstract: Economy plays an important role in the research and development of commercial aircraft. Under the premise of ensuring aircraft performance and safety, manufacturers continue to pursue cost reduction. With the goal of reducing the maintenance cost of commercial aircraft and the aircraft preventive maintenance process as the main object, this research applies the system dynamics principle to analyze the dynamic characteristics of aircraft maintenance costs, analyze the laws of the occurrence and development of aircraft maintenance costs, establish a general model and conduct simulation analysis, so as to provide a way for the prediction, analysis and control of commercial aircraft maintenance costs, and also to control the full life cycle cost of commercial aircraft Provide effective means to meet the economic objectives of commercial aircraft.

1 INTRODUCTION

In the process of developing commercial aircraft, all countries in the world have put forward the requirements of safety, comfort, environmental protection and economy without exception. Among them, safety, comfort and environmental protection are no longer difficult problems in technology. Therefore, aircraft manufacturers have put economy in an important position when developing new generation aircraft. In short, on the premise of ensuring aircraft performance, safety and reliability, It has the lowest R&D cost, manufacturing cost and operating cost.

However, some aircraft manufacturers often focus on R&D costs and manufacturing costs for their own interests and other factors, ignoring the overall consideration of operating costs. As we all know, R&D and design determine more than 50% of the cost of products, and the proportion of aircraft products will be higher (Pu 2014). Therefore, once the products are finalized, the later manufacturing costs and operating costs will be basically fixed, and it is difficult to reduce the space, which will bring great maintenance cost pressure to airlines after removing variable costs such as fuel in later operations. For example, the annual aircraft maintenance cost of the US military has reached more than 20 billion US dollars. Since the 1980s, this cost has been close to the sum of its research and development costs and procurement costs, accounting for 14.2% of the total defense expenditure. At present, it is difficult to obtain maintenance cost related data of major airlines in the world, but the situation is generally similar.

With the goal of reducing the maintenance cost of commercial aircraft and the aircraft preventive maintenance process as the main object, this research applies the system dynamics principle to analyze the dynamic characteristics of aircraft maintenance costs, analyze the laws of the occurrence and development of aircraft maintenance costs, establish a general model and conduct simulation analysis, so as to provide a way for the prediction, analysis and control of commercial aircraft maintenance costs, and also to control the full life cycle cost of commercial aircraft Provide effective means to meet the economic objectives of commercial aircraft.

2 CAUSALITY ANALYSIS

System Dynamics (SD) is a discipline that closely combines system engineering theory with computer simulation to study the structure and behavior of

[a] https://orcid.org/0000-0002-4850-1686

Li, P.
Cost Analysis of Preventive Maintenance for Commercial Aircraft Based on System Simulation.
DOI: 10.5220/0012073300003624
In *Proceedings of the 2nd International Conference on Public Management and Big Data Analysis (PMBDA 2022)*, pages 280-284
ISBN: 978-989-758-658-3

system feedback. It absorbs the essence of chaos theory, information theory, cybernetics, and topology, and believes that the behavior mode and characteristics of a system mainly depend on its internal structure (Li 2006). Only by taking the whole system as a feedback system can correct conclusions be drawn. In 1999, the US military C-17 project office first noticed that the system dynamics method can be used in cost estimation, and the cost of different activities under different circumstances can be well expected.

Preventive Maintenance described in this study is all activities to prevent aircraft failures or serious consequences caused by failures and keep them in a specified state. These activities include: wiping, lubrication, adjustment, inspection, regular repair and replacement, etc. The purpose is to find and eliminate potential faults, which have some characteristics such as complexity, integrity, connectivity, dynamics, stability, etc. (Figure 1). From the perspective of cost, the increase of preventive maintenance activities will definitely lead to the increase of preventive maintenance cost, and will also reduce the cost of corrective maintenance, which will also have a certain impact on spare parts storage costs and maintenance personnel training costs. The theory and method of system dynamics can solve this problem well.

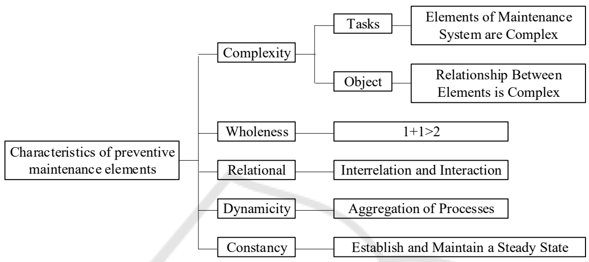

Figure 1: Characteristics of Preventive Maintenance Elements.

Preventive maintenance is generally divided into four forms: regular maintenance, condition based maintenance, advance maintenance, and failure inspection, which will consume corresponding resources and may be different from each other (Gan 2005). Therefore, in order to accurately estimate the preventive maintenance cost, it is necessary to first understand the preventive maintenance support activities of similar commercial aircraft models through the maintenance plan, then model the maintenance support activities of newly developed models, and apply the system dynamics method to evaluate the maintenance support cost of the whole life cycle. The influencing factors of preventive maintenance cost are shown in Figure 2.

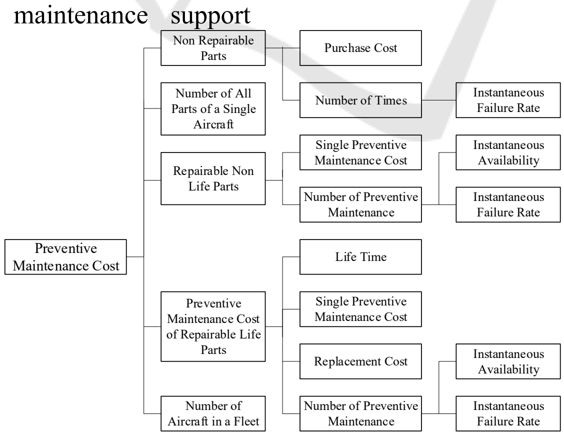

Figure 2: Influencing Factors of Preventive Maintenance Cost.

Causality analysis is very important to establish an accurate and reasonable system dynamics model (Li 2006). The causal loop diagram (CLD) is an important tool to represent the feedback structure of the system. It contains multiple variables, and the variables are connected by arrows indicating the causal relationship. The causal loop of the preventive maintenance cost influencing factors listed in Figure 2 is shown in Figure 3. The NRP means Non Repairable Parts, RLP means Repairable Life Parts and RNLP means Repairable Non life Parts of the aircraft are all maintained in a fixed time interval. In the early stage of aircraft operation, the failure rate is relatively low, and the time interval between scheduled maintenance can be relatively long; After a long period of aircraft operation, with aging and frequent failures, the preventive maintenance interval should be reduced. In the figure, there are 7 stocks and 7 flows, a constant number of organic groups of aircraft, preventive maintenance costs for single repairable life parts, etc.

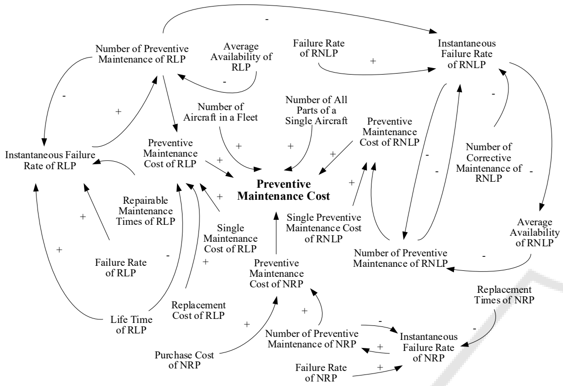

Figure 3. Cause and Effect Loop Diagram of Preventive Maintenance Cost.

3 CASES AND MODELS

The relevant boundary conditions in this study are as follows:

- All expenses incurred are present value, without considering inflation;
- The fleet has 24 single channel trunk aircrafts, each of which has a service life of 20 years, and each aircraft has an average annual flight time of 300 hours;
- The preventive maintenance of the fleet only considers scheduled maintenance, and the time interval will be adjusted as the aircraft ages; Corrective maintenance only includes repair and replacement of parts; The storage management cost of spare parts is only affected by the number of spare parts, that is, the storage cost of each spare part is a fixed value; The annual personnel training cost is fixed.
- Each aircraft has 100000 parts, and there are only three types of parts: 60000 repairable parts with life, 20000 repairable parts without life, and 20000 non repairable parts. The failure rate of all parts is the same. The cost of a single repair is a fixed value, and the cost of tools/facilities for inspection and repair is also a fixed value.
- The field maintenance rate of aircraft fault parts is a fixed value.
- When a component fails, the improvement of reliability after repair or replacement is considered as the improvement of the reliability of the original component and the continuation of the original component, but the instantaneous failure rate is reduced.

Other detailed assumptions will not be elaborated.

The preventive maintenance interval of the aircraft is determined by the method of timing maintenance interval T:

$$\overline{A} = \frac{1}{\lambda T}\left(1 - e^{-\lambda T}\right)$$

Where $\overline{A}$ is the average availability, λ Is the failure rate. In engineering calculation, the time interval T is not easy to express, so the $e^{-\lambda T}$ in the formula is decomposed by Taylor:

$$e^{-\lambda T} = 1 + \frac{-\lambda T}{1!} + \frac{(-\lambda T)^2}{2!} + \frac{(-\lambda T)^3}{3!} + \cdots + \frac{(-\lambda T)^n}{n!}$$

Generally, according to the requirements of airworthiness regulations, the failure rate of aircraft components λ Are extremely low, even reaching 10-9, so λ 3 It is small enough, so the first three terms of $e^{-\lambda T}$ Taylor decomposition formula are approximated:

$$\overline{A} = \frac{1}{\lambda T}\left(1 - e^{-\lambda T}\right) \approx \frac{1}{\lambda T}\left\{1 - \left[1 + \frac{-\lambda T}{1!} + \frac{(-\lambda T)^2}{2!}\right]\right\} \Rightarrow T \approx \frac{2\left(1-\overline{A}\right)}{\lambda}$$

Then, the DAPCA analysis model of RAND Company in the United States is used for simulation analysis and estimation, and the PRICE model is used for parameter estimation and verification.

4 ANALYSIS OF SIMULATION RESULTS

This study observed the change of maintenance support cost by increasing the frequency of preventive maintenance (Figures 4 and 5): when the maintenance frequency increased by 10%, the maintenance support cost decreased; When the maintenance frequency is increased by more than 20%, the maintenance support cost will increase significantly, which deviates from the traditional understanding. Therefore, it is suggested that the higher the preventive maintenance frequency is, the better. A more reasonable cycle balance point needs to be found.

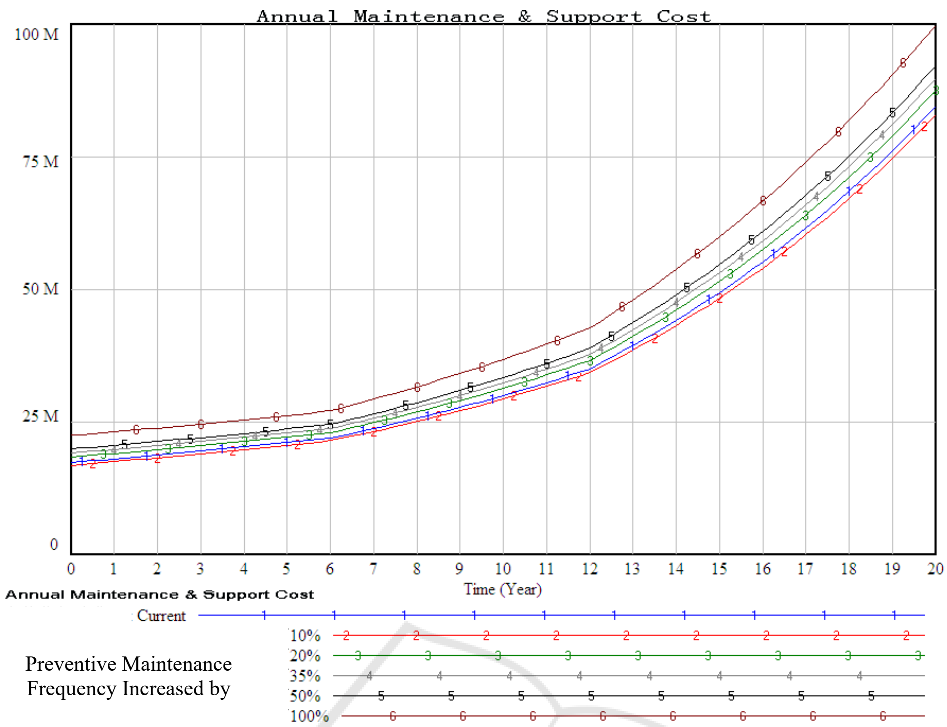

Figure 4: The Influence of Preventive Maintenance Frequency Change on Annual Maintenance Support Cost.

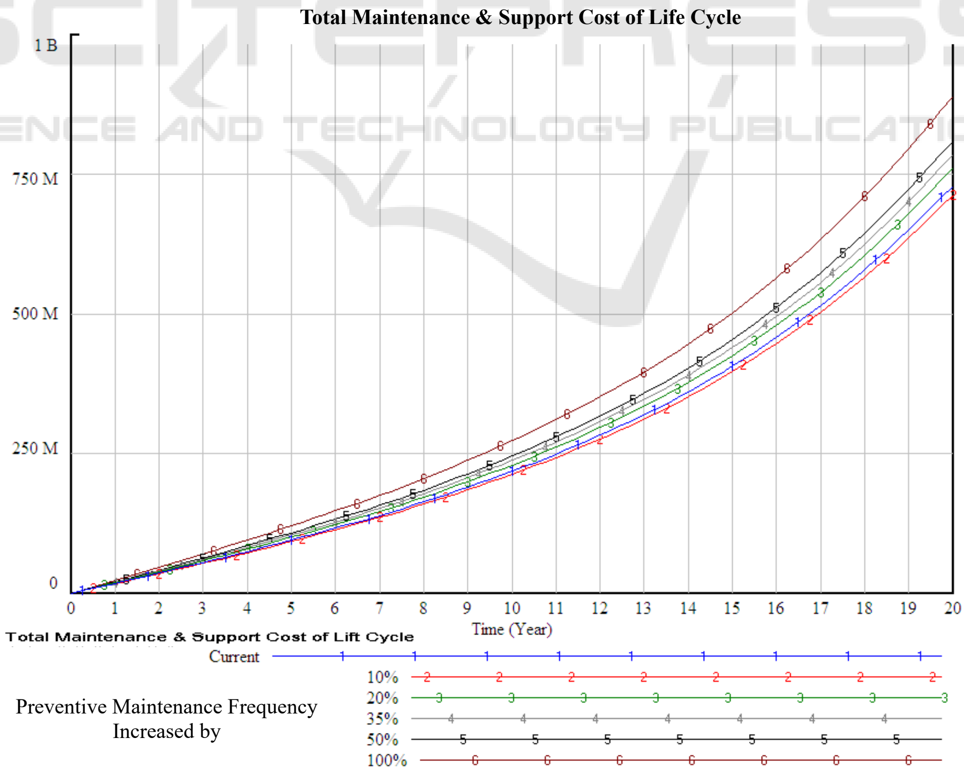

Figure 5: Influence of Preventive Maintenance Frequency Change on Total Life Cycle Cost.

5 CONCLUSION

This study provides an effective method to solve the cost estimation of aircraft maintenance support system with complex influencing factors and long duration by applying system dynamics. Through case based simulation analysis, the impact of failure rate and preventive maintenance rate on maintenance cost is analyzed, and suggestions are put forward to reduce the failure rate of aircraft parts and determine reasonable preventive maintenance frequency, This will enable the winning manufacturer to pay full attention to the aircraft development process and take effective measures to reduce the life cycle cost to achieve the purpose of economy.

REFERENCES

C. D. Purvis. (2001). Estimating C-17 Operating and Support Costs: Development of a System Dynamics Model. R. Air force institute of technology.

Gan M., Kang J. (2005). Military Equipment Maintenance Engineering. M. Beijing: National Defense Industry Press.

Guo S. H. (2013). Thoughts on Effectively Controlling Airline Aircraft Maintenance Costs. J. Foreign Investment in China (20), 130-131.

Jia R. A., Hu L., Ding R. H., et al. (2001). System Dynamics Simplified Flow Rate Basic Tree Entry Model and Application. J. System Engineering Theory and Practice, 21 (10): 137-144.

Jia R. A., Wu F., Xu N. S. (1998). SD flow rate basic tree modeling method. J. System Engineering Theory and Practice, 18 (6): 90-95.

Li Z. Q., Chen Y. L. (2011). Research on aircraft condition based maintenance strategy and model. J. Aviation Science and Technology, 2011 (03): 28-30.

Macia N. F.， Thaler G. J. (2006). Dynamic System Modeling and Control. M. Translated by Li Naiwen and Sun Jianghong. Tsinghua University Press.

Pu L., Huang Z. D. (2014). System dynamics analysis of aircraft maintenance training cost. J. Civil Aircraft Design and Research, 4 (2): 48-50.

Shao G. X., Qiu J. C., Li Z. & Liu J. (2012). System dynamics analysis of aviation equipment preventive maintenance cost. J. Aerospace Science and Technology (03), 65-70.

Xu Z. Y., Peng Y. M. (1997). Research on Life Cycle Cost Analysis of Aeroengines. J. Aviation Systems Engineering, 1997 (5): 39-44.