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Research Article

Analysis of Canadian Armed Forces CH149 Aircraft Replacement/Overhaul Options#

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Abstract: Aging aircraft present significant technical, economical, and operational challenges for military decision makers. As aircraft mature beyond their planned service lives, their maintenance needs may become less predictable and their overall operational availability tends to decrease. Operations and Maintenance (O&M) costs normally increase over time and eventually become prohibitive, thereby providing strong evidence that the aircraft should be replaced. This paper presents an analysis of the Canadian Armed Forces CH149 aircraft replacement and overhaul options. The analysis identified three potential decision regions for the aircraft replace/lease/upgrade options, depending on the O&M cost reduction factor and the lease cost. Sensitivity and risk analyses were conducted to assess the impact of key parameters on the decision regions.

1. Introduction

Aging aircraft present significant technical, economical, and operational challenges for military decision makers. As aircraft mature beyond their planned service lives, their maintenance needs may become less predictable. Corrosion, for example, may require additional inspections and repairs. Aircraft may also become less resilient with age, so that random events pose increasingly serious maintenance challenges. As aircraft age, it is expected that increasing Operations and Maintenance (O&M) costs will eventually become prohibitive, thereby suggesting that the aircraft should be replaced. From an operational perspective, the overall operational availability (Ao) of military aircraft tends to decrease with age. Ao is an important consideration in the evaluation of system performance, readiness, and sustainability.

This paper presents an analysis of the Canadian Armed Forces CH149 aircraft replacement/ overhaul options. The CH149 Cormorant is Canada's primary search-and-rescue (SAR) helicopter. Since delivery, the CH149 fleet has not reached its Ao target set in the original statement of requirements. In addition to lower than expected Ao, the O&M costs of the CH149 fleet have increased significantly over the past few years. Various unanticipated maintenance problems, such as early on-set corrosion, have contributed to degraded performance and upwardly spiralling O&M costs.

A simulation-based economic model was developed to assess the cost effectiveness of the CH149 replacement/ overhaul options [1]. The model used the Geometric Brownian Motion (GBM) [2] method to forecast the aircraft O&M cost trends and applied cost comparison methods of engineering economics [3] to assess the cost effectiveness of the CH149 replacement/ overhaul options. GBM is a continuous-time stochastic process in which the logarithm of the randomly varying quantity follows a Brownian motion with drift. GBM accommodates random events through a diffusion process and upward trends through a drift process. Three proposed aircraft replacement and overhaul options (Upgrade, Lease, and Replace) were investigated.

The Upgrade option considers upgrading the current CH149 fleet (14 aircraft) and expanding it with six additional (new) aircraft. It is assumed that upgrading the current CH149 aircraft would reduce their O&M costs by a factor called the O&M cost reduction factor. The Lease option considers replacing the current CH149 fleet with 20 leased aircraft of similar operational capabilities for a fixed annual cost called the lease cost. The Replace option considers replacing the current CH149 fleet with 20 new aircraft of similar capabilities. For simplicity, it is assumed that 10 aircraft will be delivered at the beginning of the project and the remaining 10 aircraft will be delivered five years later. In this case, the current CH149 fleet would remain in service until the delivery of the last aircraft.

2. O&M Cost Process

To assess the cost effectiveness of the aircraft replacement/ overhaul options, historical O&M costs of the current CH149 fleet were collected and analysed. A data set of ten annual O&M costs per aircraft for the years 2003 to 2012 was obtained from the Defence Financial Management Accounting System: 0.677, 1.623, 2.269, 2.422, 3.746, 5.559, 4.885, 5.811, 7.509, 8.030 ($M). The first step in the analysis is to test the GBM model assumptions using the data sample. There are a number of theoretical goodness-of-fit tests that can be applied for small samples, and the two of the best known distance tests are Anderson-Darling and Lilliefors [4]. The application of these tests to the O&M cost data gave a p-value of 0.59 for Anderson-Darling and 0.50 for Lilliefors, indicating a failure to reject the null hypothesis that the sample comes from a normal distribution at a significance level of 5%. To test the data for the independence assumption, the sample autocorrelation function (ACF) of the data was calculated and compared with the theoretical ACF derived from the GBM process. The test indicates that most of the data is confined to the 95% confidence bands of the autocorrelation function, except for lags 1 and 2. At lags larger than 2, the sample ACF becomes consistent with white noise.

Using the maximum likelihood technique, the GBM model parameters (mean and standard deviation) are estimated from the O&M cost data as: $\mu = 0.25$ per year and $\sigma = 0.27$ per year1/2. Figure 1 depicts the CH149 O&M cost data and projected sample paths generated using the GBM model. The contour denotes the boundary that contains 95% confidence interval for forecasted paths using the model parameters.

3. Cost Effectiveness Analysis

The next step in the analysis is to use the economic model developed in [1] to determine the cost effective option for the CH149 replacement and overhaul. For the purpose of this paper, it is assumed that the O&M costs of the additional fleet, leased fleet and new fleet follow the same patterns (i.e., same GBM parameters) as the O&M costs of the current fleet. They are estimated by projecting the CH149 O&M cost data over time for different fleet sizes. It is also assumed that the O&M cost of a leased aircraft is higher than the O&M costs of a new aircraft by about 10% to 15% (for example). Given the lack of data, a set of hypothetical economic parameters for both the current and the new aircraft fleets was considered in the analysis. The details of the economic parameters (e.g., upgrade cost, book value of the aircraft, discount rate, etc.) can be found in [1]. Probability distributions (e.g., Program Evaluation and Review Technique) were used to represent the variability in these parameters and Monte Carlo simulation was applied to determine the expected costs of the aircraft replacement/overhaul options. The O&M cost reduction factor and the annual lease cost were used as decision variables in the study.

Figure 2 depicts three potential decision regions (Upgrade, Lease, and Replace) for the aircraft replacement/ overhaul options, depending on the O&M cost reduction factor (ρ) and the annual lease cost. The boundaries between the three regions are determined by varying the cost reduction factor and calculating the corresponding annual lease cost for a large number of simulation runs (e.g., 100,000). The analysis indicates that there is a critical value of the O&M cost reduction factor (corresponding to the intersection of the three region boundaries) as shown in Figure 2. Decision makers need to estimate the value of the O&M cost reduction factor and compare it with the critical value in order to determine the cost effective option for the CH149 replacement/ overhaul problem. In this example, the Lease region represents the cost effective option where the O&M cost reduction factor is less than 62% to 79% and the lease cost is less than a threshold lease cost of $280M. Similarly, the Replace region indicates the cost effective option when the O&M cost reduction factor is less than the 62% but the lease cost is greater than $280M. Finally, the Upgrade region represents the cost effective option when the O&M cost reduction factor is significantly high.

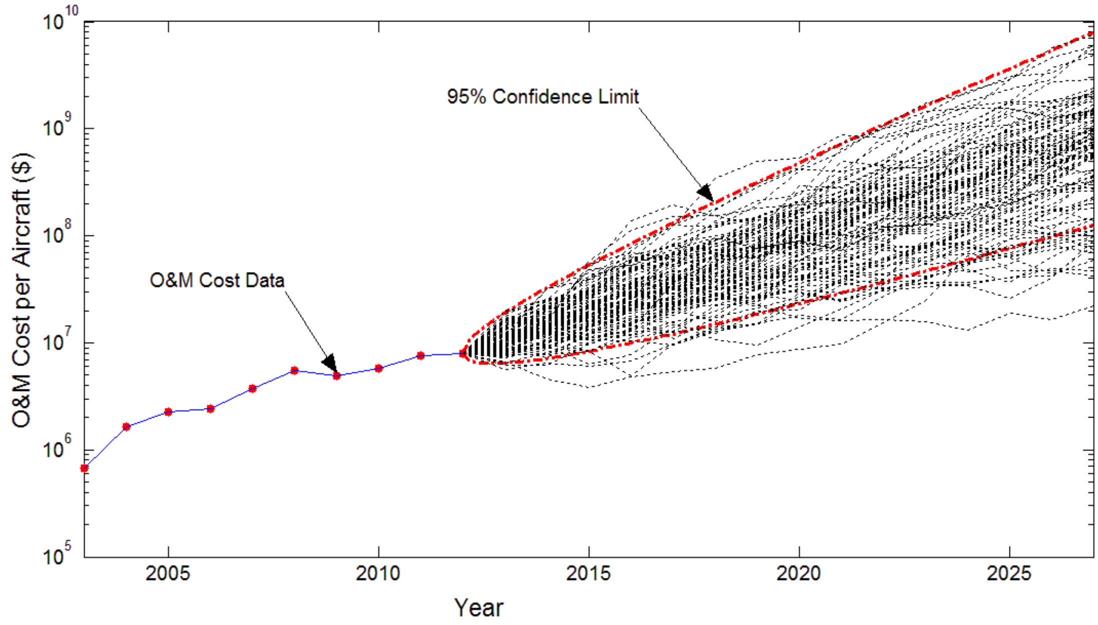

Figure 1. *Aircraft O&M cost data and projected sample paths.*

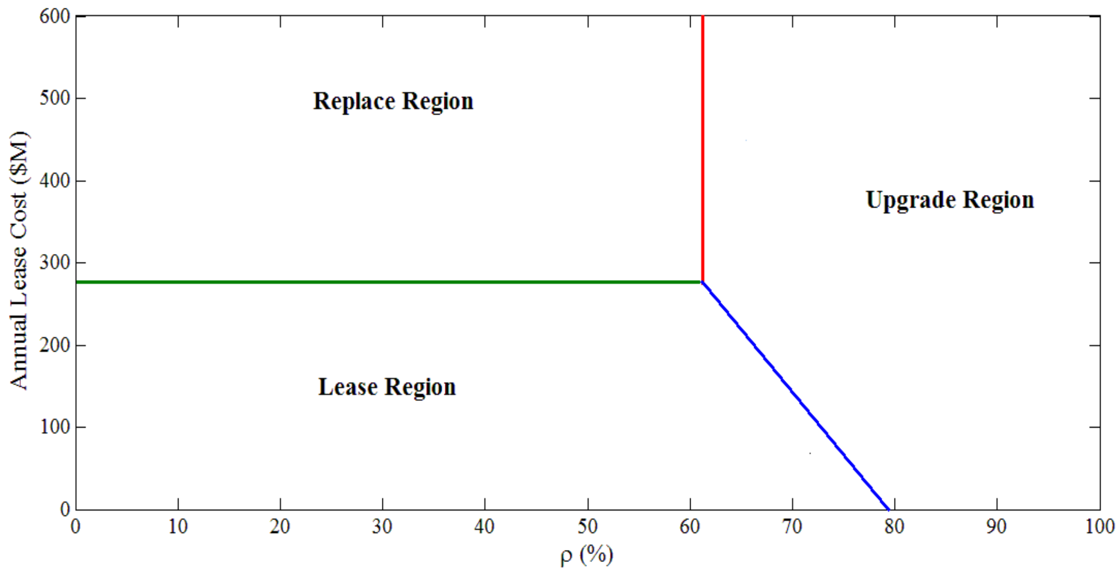

Figure 2. *Decision regions for the aircraft replacement/overhaul options.*

4. Risk and Sensitivity Analysis

An analysis was conducted to evaluate the confidence level for selecting the cost effective option for a given O&M cost reduction factor and a lease cost. The confidence level is determined by calculating the ranking probabilities of the options. Figure 3 depicts the iso-contours of the maximum ranking probabilities of the options and shows different confidence levels for the cost effective regions. The area between the cost effective regions represents the uncertainty region, where all options have comparable ranking probabilities. A sensitivity analysis was also conducted to assess the impact of key parameters (fleet size, in-service period, and O&M cost growth rate) on the cost effectiveness option. It indicates that the decision region would not be affected by a small change in the fleet size but will be sensitive to the in-service period and the O&M cost growth rate.

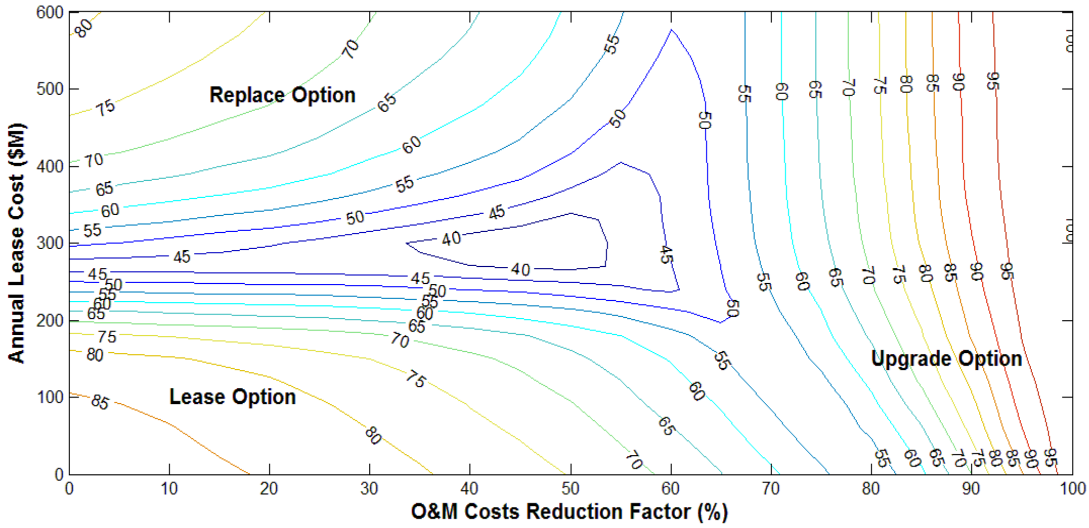

Figure 3. *Iso-Contours of the maximum ranking probabilities.*

5. Conclusions

In this paper, an analysis was conducted to assess the CH149 aircraft replacement/ overhaul options. Depending on the O&M cost reduction factor and the lease cost, three potential decision regions were identified. The analysis indicated that the Upgrade option would not be cost effective as it would not be feasible in practice to reduce the O&M costs by 80%, for example. As such, the Lease or the Replace options should be further investigated. The analysis also indicated that the decision region would not be affected by a small change in the fleet size but will be sensitive to the in-service period and the O&M cost growth rate. Future work would include an analysis of the optimal replacement age of the aircraft.

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