This product is part of the RAND Corporation monograph series. RAND monographs present major research findings that address the challenges facing the public and private sectors. All RAND monographs undergo rigorous peer review to ensure high standards for research quality and objectivity.

The Maintenance Costs of Aging Aircraft

Insights from Commercial Aviation

Matthew Dixon

Prepared for the United States Air Force

Approved for public release; distribution unlimited

RAND PROJECT AIR FORCE

The research reported here was sponsored by the United States Air Force under Contract F49642-01-C-0003. Further information may be obtained from the Strategic Planning Division, Directorate of Plans, Hq USAF.

Library of Congress Cataloging-in-Publication Data

Dixon, Matthew C.
The maintenance costs of aging aircraft : insights from commercial aviation / Matthew Dixon.
p. cm.
Includes bibliographical references.
ISBN-13: 978-0-8330-3941-5 (pbk. : alk. paper)
1. Airplanes, Military—United States—Maintenance and repair. 2. United States. Air Force—Aviation supplies and stores. I. Title.

UG1243.D568 2006
358.4'183—dc22

2006028468

Published 2006 by the RAND Corporation
1776 Main Street, P.O. Box 2138, Santa Monica, CA 90407-2138
1200 South Hayes Street, Arlington, VA 22202-5050
4570 Fifth Avenue, Suite 600, Pittsburgh, PA 15213-2665
RAND URL: http://www.rand.org/
To order RAND documents or to obtain additional information, contact
Distribution Services: Telephone: (310) 451-7002;
Fax: (310) 451-6915; Email: order@rand.org

Summary

This monograph examines "aging effects"—i.e., how commercial aircraft maintenance costs change as aircraft grow older. Although commercial aircraft clearly differ from military aircraft, commercial aviation aging-effect estimates might help the Air Force to project how its maintenance costs will change over time.

Literature Discussion and Prior Work

There is a large body of literature on aging aircraft, much of which focuses on military aviation. Recent studies have generally found positive aging effects (costs rising with age), although the estimated magnitude of the effects has varied considerably (see pp. 5–13).

Boeing's 2004 analysis of commercial aviation aging effects (Boeing, 2004a) is the most direct intellectual forerunner to this current study. Boeing computed a "maturity curve" for airframe maintenance costs. Boeing found airlines' airframe maintenance costs increase as aircraft come off warranty, then enter a stable "mature" period after the first D check[1] (depot-level heavy maintenance), and then resume rising after about 10–14 years of service and the second D check (see pp. 13–15). Of course, the observed jump in aircraft maintenance costs as aircraft come off warranty does not represent an increase in maintenance as much as a transfer of maintenance cost responsibility from the aircraft's manufacturer to its owner.

---

1 A *D check* is a complete structural check and restoration.

Commercial Aviation Maintenance Data

Form 41 data are reports that U.S. commercial airlines are required to file with the Department of Transportation (DoT) indicating their maintenance costs and flying hours. RAND gathered Form 41 data from the DoT on maintenance costs going back to the 1960s. Separately, RAND obtained data on airlines' average fleet ages by calendar year.

The estimation strategy was to run a log linear regression with the natural logarithm of maintenance cost per flying hour as the dependent variable and various independent variables including average fleet age. The coefficient on the age variable in such a regression would estimate the age effect, i.e., how maintenance costs typically change as aircraft age, other things being equal.

Results

The RAND study team ran three separate log linear regressions, computing age effects for aircraft 0–6 years old, 6–12 years old, and more than 12 years old. Figure S.1 depicts the results (with the total maintenance costs per flight hour for a six-year old aircraft normalized to 1.0).

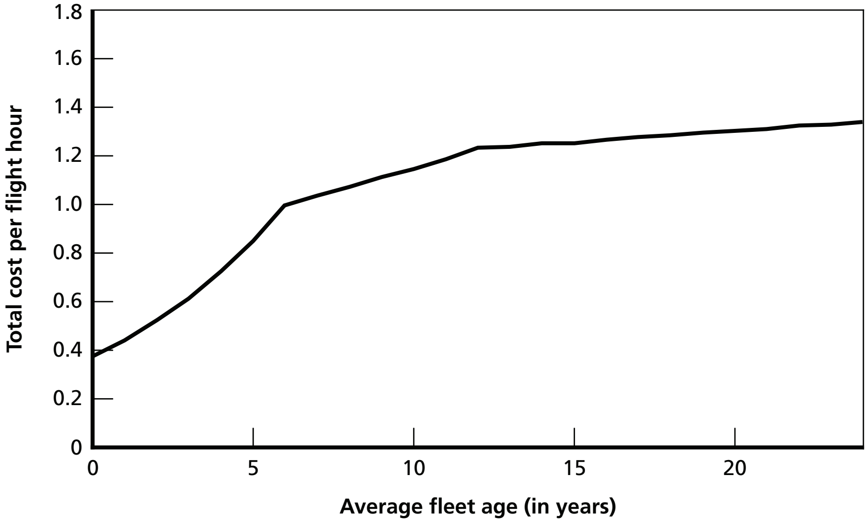
This study found that young aircraft have considerable age effects (an estimated 17.6 percent annual rate of increase in maintenance cost per flying hour, with a standard error on that estimate of 1.8 percent). This age effect reflects aircraft coming off warranty, which increases airline maintenance costs.

For mature aircraft, ages 6–12, a 3.5 percent annual age effect was found, with a standard error of 0.8 percent.

Most intriguingly, an age effect of 0.7 percent, not statistically significantly different from zero, was computed for aircraft over 12 years of age (see pp. 27–28).

One reason that these findings differ from Boeing's maturity curve is that RAND analyzed total maintenance costs, including engine and

Figure S.1
Age Effects Estimated with Form 41 Data



RAND *MG486-S.1*

overhead costs, not simply airframe maintenance costs. Airframe-maintenance cost growth shows a more convex growth pattern than Figure S.1's depiction of total maintenance cost growth. Engine maintenance costs, by contrast, seem to remain very flat as aircraft age (after an initial jump in the first years of operation). Airframe maintenance costs are only about a third of total maintenance costs in the data analyzed (see pp. 29–31).

RAND experimented with other regression specifications, e.g., airline-specific dichotomous (dummy) variables and endogenous selection of age breaks. None of these alternative specifications provided meaningfully different findings (see pp. 32–35).

Potential Bias in Estimated Age Effect

The study team was concerned that airlines were prematurely retiring "poorly aging" fleets and that such early retirements caused Figure S.1 to be artificially concave.

The study team analyzed 21 fleets that were retired before an average age of 20 years. The team did not find evidence that the fleets had unusual aging effects. It was found, however, that these early-retired fleets were unusually expensive in the first 12 years of their lives. Cost problems may have encouraged airlines to retire these fleets, but there was no evidence that those problems were worsening unusually rapidly (see pp. 37–40).

RAND did not find that fleet-level retirement selection bias causes Figure S.1's concavity.

Conclusions

If one believes that commercial aviation experience is germane to the Air Force, this study suggests that total aircraft maintenance costs may plateau, at least for certain aircraft ages. Pessimism about the future trajectory of total maintenance costs may not always be correct. RAND also found different cost patterns for different types of aircraft maintenance, e.g., airframe maintenance versus engine maintenance.