REDUCED Maintenance Costs

FOR THE 737-600/-700/-800/-900 FAMILY OF AIRPLANES

Reducing fleet maintenance costs is a key issue affecting any airline's bottom line. During the development of the 737-600/-700/-800/-900 family of airplanes, Boeing initiated a program to lower the airplanes' overall airframe maintenance costs by as much as 15 percent, relative to the earlier 737-300/-400/-500 family. The program, called *Maintenance Cost Reduction by Design*, included participation by 21 airlines from around the world and provided extensive in-service experience upon which to draw.

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A major concern of airlines in today's competitive business environment is lowering their airplane-related operating costs (AROC). These costs directly affect an airline's cash flow and ultimately its financial health. An airline's total AROC falls into six categories: flight and cabin crews, fuel, maintenance, navigation and landing fees, ownership and spares, and depreciation (fig. 1).

A sizable part of AROC is related to airplane maintenance. Although maintenance costs, as a percentage of AROC, will vary—depending on such factors as airplane type, average flight segment length, and airplane age—typical maintenance costs range from approximately 10 to 20 percent of AROC. These percentages may seem somewhat small at first glance, but they represent significant sums of money. Large carriers, for example, have maintenance budgets in excess of $1 billion.

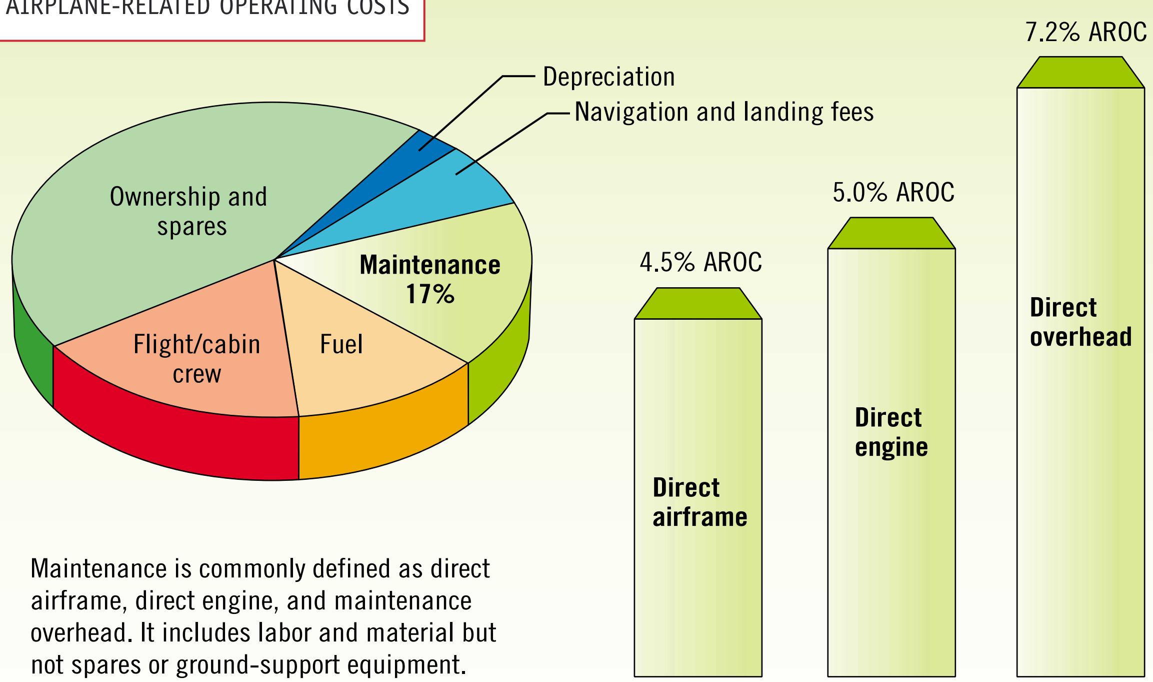
From the early stages of airplane development, the 737-600/-700/-800/-900 team strove to lower maintenance costs and give the airlines the airplane with the most competitive operating cost possible. The target for overall reduced airframe maintenance costs was 15 percent, relative to the earlier 737-300/-400/-500 family, which had set the standard for lowest operating costs in its class. The 15 percent reduction was considered an attainable, though challenging, goal that would significantly increase the airplanes' value to airline customers.

Although airplane type is a major determinant of an airline's maintenance cost, it is not the only one. Ultimately, the realized improvement in maintenance costs for a particular airline also will be a function of other factors including that airline's maintenance policies and procedures, operating parameters, and labor market.

This article discusses

1. Maintenance cost savings achieved through airplane design.
2. Actual in-service savings realized by airlines.

FIGURE 1 AIRPLANE-RELATED OPERATING COSTS



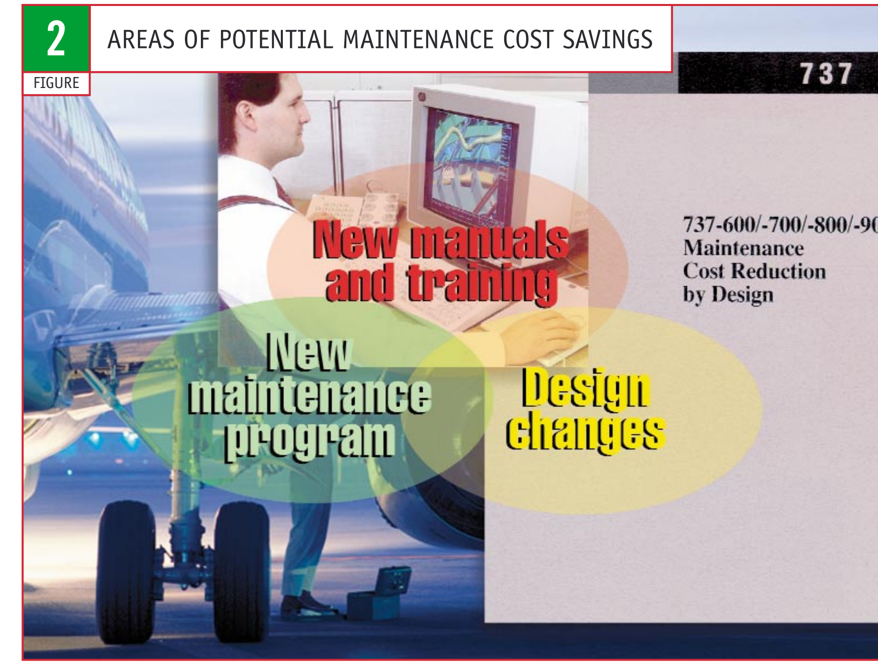
Maintenance is commonly defined as direct airframe, direct engine, and maintenance overhead. It includes labor and material but not spares or ground-support equipment.

1 MAINTENANCE COST SAVINGS ACHIEVED THROUGH AIRPLANE DESIGN

To reduce maintenance costs by 15 percent, the 737-600/-700/-800/-900 airplane program leveraged potential savings from three areas (fig. 2):

- Airplane design improvements.
- Scheduled maintenance program improvements.
- Improved maintenance documents and training.

FIGURE 2 AREAS OF POTENTIAL MAINTENANCE COST SAVINGS



Airplane design improvements. During the planning stages of the 737-600/-700/-800/-900 program, a basic design philosophy was followed known as *value-added technology*. Essentially, the design team made discretionary design changes to the airplane only if they offered a better value to the airline customer in terms of superior economical performance, which included lower maintenance costs.

The design team's approach focused on a number of key goals: using digital instead of analog systems, lowering system part counts, having more common parts among models, simplifying system designs, improving corrosion protection, enhancing fault identification, and providing better access to parts for maintenance.

Many of the specific design changes were directly attributable to airline customer inputs (fig. 3). Examples of design changes that enhanced maintainability include the following:

- A completely new wing with double-slotted continuous span flaps with 30 percent fewer parts for improved maintainability.
- Wing leading-edge panels designed for easier access by maintenance crews.
- A simplified main landing gear assembly for enhanced maintainability and a 30 percent reduction in brake change time.
- Improved access to line replaceable units (LRU) and components, maximum use of quick-disconnect line fittings, and improved ground-support equipment, which reduced engine removal and installation time by more than 50 percent.
- A redesigned auxiliary power unit (APU) for improved access and maintainability.
- Single-point-of-service vacuum lavatories that significantly lower servicing time at the gate.
- Redesigned electronics and equipment bays for improved access to remove and repair components.
- New CFM56-7 engines for 15 percent lower maintenance costs when compared with the equivalent maximum thrust rating of the CFM56-3 engine.
- Improved consistency and usability of built-in test equipment (BITE) user interfaces to reduce time and errors during airplane system troubleshooting.

Another vital aspect of the design improvements involved corrosion prevention. This included increased sealing between critical parts, additional protective finishes such as primer applied to detailed parts, and improved drainage that included a door threshold gutter redesign. These changes were made not only to reduce maintenance costs during an operator's heavy maintenance checks and structural inspections but also to extend the service life of the airplane.

Other specific design improvements included incorporation of a digital cabin pressure control system (CPCS) in lieu of an analog system, which reduced the number of mechanical parts. The CPCS redesign also added the capability for BITE to more quickly identify problem areas, such as individual LRUs or wiring anomalies. This reduced mechanics' fault-isolation troubleshooting time. Also, the BITE capability increased the systems' mean time between unscheduled removals (MTBUR) by approximately 75 percent and reduced the initial provisioning costs for spare parts by as much as 45 percent. By increasing the MTBUR, components remain on the airplane for a longer time, thereby reducing the inventory requirement for additional spare parts.

Another design improvement involved integrating the stall management and yaw damper computers into a single unit. Eliminating the yaw damper computer reduced spares provisioning and maintenance costs and improved system reliability.

In the flight deck systems, reliability, redundancy, and BITE were enhanced to make the systems less susceptible to errors (i.e., more fault tolerant) and improve their mean time between failures (MTBF) by 62 percent. System optimization, in part through improved fault tolerance capability and MTBF, allowed the design team to reduce the total number of parts in the flight deck systems by 23 and provide the airlines with increased dispatch reliability.

For these and many other design improvements, a detailed analysis was done at the system level to ensure that the comprehensive cost reductions reached the 15 percent reduction target. Engineers used three-dimensional computer (digital) modeling and employed human factors principles for all design work. The use of digital modeling provided the means to perform detailed maintainability analysis. The approach employs maintenance access solids (MAS), which are solid design elements used to reserve space for accessing, removing, and installing parts. The digital computing data sets verified that airplane components could be readily accessed and removed during the design phase and in-service maintenance.

The human interface also was digitally defined as part of the MAS design approach. The MAS design was used to examine the areas of space, or envelopes, needed to conduct various types of inspections: borescope envelopes, access envelopes for tool sweeps and the removal and installation of components, and visual envelopes for line-of-sight access to inspect components. Each envelope was verified using detailed three-dimensional digital reviews to ensure a high level of airplane maintainability.

Scheduled maintenance program improvements.

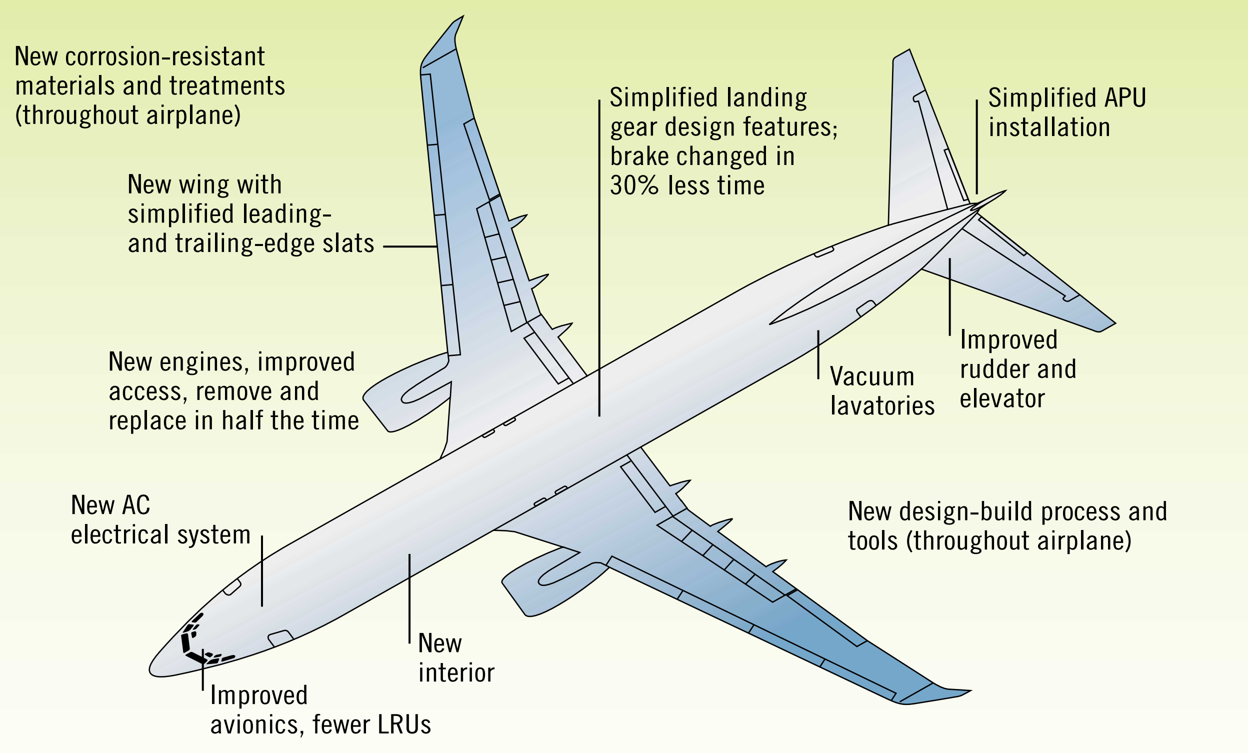
The reduced scheduled maintenance activities in the 737-600/-700/-800/-900 airplanes are the result of design changes at the airplane system level and an integration of industrywide maintenance practices developed by the Maintenance Steering Group (MSG), a committee comprising airframe manufacturers, airlines, and U.S. Federal Aviation Administration representatives. The latest iteration of these maintenance practices is MSG Level 3, Revision 2 (MSG-3 Rev. 2).

Design changes. Design improvements at the airplane system level reduced scheduled maintenance activities by extending maintenance intervals or eliminating tasks altogether. This provides the airlines with maximum flexibility and use of both the airplane and airline maintenance resources. The result is lower costs to airlines for scheduled airframe maintenance checks, which account for 18 to 20 percent of overall maintenance costs.

One example of reduced scheduled maintenance by system redesign is the trailing-edge flap-drive system. The system was redesigned to last the life of the airplane, with no anticipated overhauls, by switching from an oil-filled reservoir to grease lubrication and using 100 percent corrosion-resistant steel material in lieu of the original chrome plating to eliminate corrosion wear. As a result, the scheduled maintenance intervals were extended from 20,000 flight cycles to 75,000 flight cycles.

The air-conditioning packs also were redesigned, based on in-service experience and customer inputs, which indicated that the 737-300/-400/-500 two-wheel (turbine and compressor) ball-bearing air-cycle machine and the ram-air-system turbofan required oil servicing. The air-conditioning packs were redesigned to a three-wheel (turbine, compressor, and fan) air-bearing cycle machine, which required no scheduled maintenance service.

FIGURE 3 EXAMPLES OF DESIGN CHANGES TO THE 737-600/-700/-800/-900



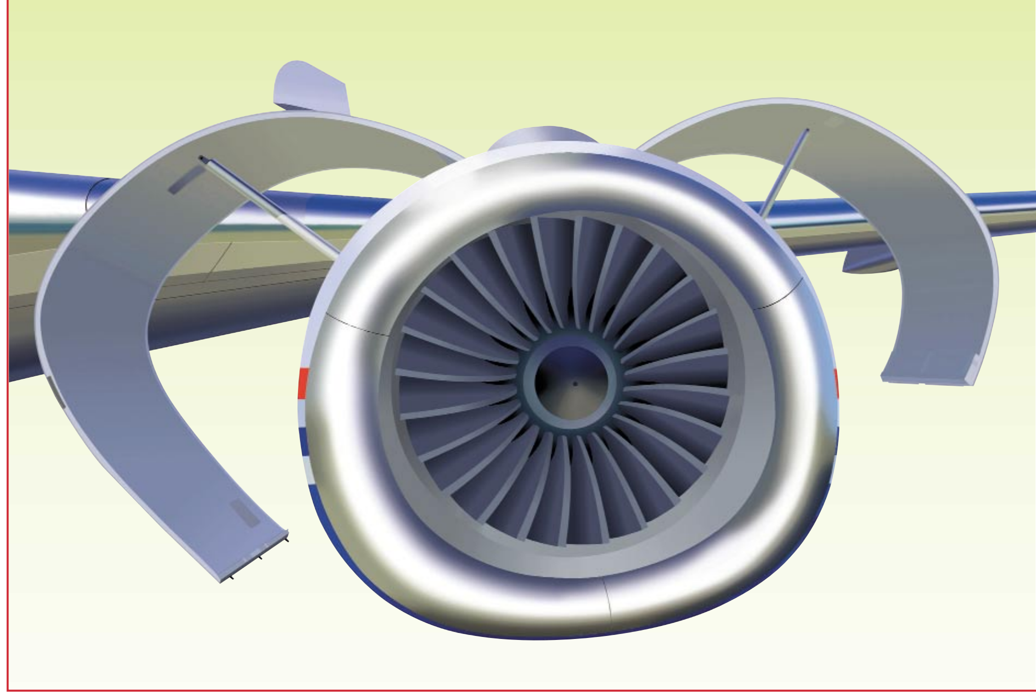
Design improvements in the airplane's electrical power system also reduced scheduled maintenance activities. Based on in-service information, designers switched from a 50- to a 90-kVA electrical power system and selected an integrated drive generator in place of the constant speed drive to improve overall system reliability and extend the intervals between system oil-level checks and filter changes.

Maintenance planning document. The 737-600/-700/-800/-900 team analyzed scheduled maintenance activities using the MSG-3 Rev. 2 process along with supporting in-service 737-300/-400/-500 scheduled maintenance data. MSG-3 Rev. 2 is the same process used on the 777. The process uses airplane system analysis to identify system redundancies, system reliability, past system safety records, and the system safety factor. This analysis leads to a more efficient maintenance program.

The 737-600/-700/-800/-900 maintenance program had a reduction in scheduled maintenance activities compared with a 737-300/-400/-500 maintenance program in 1998. Historical data from the 737-300/-400/-500 maintenance program served as a baseline and were used to improve the 737-600/-700/-800/-900 maintenance program.

The MSG-3 Rev. 2 analysis focused on the following areas: applicable and effective tasks, clear distinction between safety and economic tasks, system-level analysis of reliability and redundancy capabilities, integration of corrosion prevention and control and structural inspections, and preclusion of systems tasks by zonal inspection where applicable. The analysis optimized maintenance intervals for each task based on design and manufacturing improvements, accumulated operator experience, and reliability data on similar airplane systems and parts.

In addition, the maintenance tasks for the 737-600/-700/-800/-900 were not prepackaged into more extensive maintenance inspections performed on a periodic basis (i.e., letter checks such as A-checks and C-checks). Not tying tasks to a predefined major maintenance check allows airlines to more efficiently implement tasks into their maintenance programs based on their specific airplane use and operation. The specific maintenance intervals for individual tasks provided the airlines with greater flexibility in the establishment of their maintenance programs.



Improved maintenance documents and training.

Improved manuals and training also were integral to the overall plan to reduce maintenance costs by 15 percent. These improvements involved fault reporting and isolation manuals, the structural repair manual, digital formatting, and training.

Fault reporting manuals (FRM) and fault isolation manuals (FIM). In-service experience on earlier airplane models had shown no standardized, consistent method of isolating and reporting faults. The troubleshooting information for mechanics was placed throughout the maintenance manual. These factors resulted in higher numbers of components being removed by maintenance crews that later were found not to have any faults (i.e., no-fault-found component removals).

To remedy the situation, new FRMs and FIMs were written to the latest Air Transport Association (ATA) specification, which is based on the improved understanding of the maintenance crews' informational needs. These manuals made for more precise identification of faults between flight and maintenance crews, reduced troubleshooting lookup time, and standardized reporting of faults. These manuals, combined with flight crews' advance notification to ground crews of incoming faults, reduced no-fault-found component removals.

Structural repair manual (SRM). In conjunction with improved FRMs and FIMs, the SRM was enhanced. Developed in accordance with the new ATA specification, the SRM reflects the updated ATA chapter designations for each airplane system and subsystem. The SRM includes more detailed structural identification, resulting in less research time for mechanics. It also contains more comprehensive, user-friendly reports and sets larger allowable damage limits on systems and parts. In addition, the SRM reduces or eliminates areas of the airplane once considered critical to airplane safety and performance (i.e., critical zones). The SRM also documents more temporary repairs and extends temporary repair time intervals.

Digital format. Data from published studies and airline surveys showed that mechanics on average spent 25 percent of their time researching troubleshooting and repairs in the FIMs and aircraft maintenance manuals (AMM). This activity was hampered because documentation only was available on paper or microfilm, where copy quality at times was poor. The manual process of turning pages or advancing microfilm cartridges to locate the desired information was time consuming. Also, there was no online access to engineering drawings. To address this issue, Boeing documents were made available in a digital format retrievable from a CD-ROM. Software products such as the Portable Maintenance Aid (PMA) allow quick access to data through hyperlinks while featuring enhanced search and navigation capabilities. Online access to maintenance documentation and engineering drawings and documents was made available through the MyBoeingFleet.com web site to reduce the time mechanics spent researching, viewing, and printing documents.

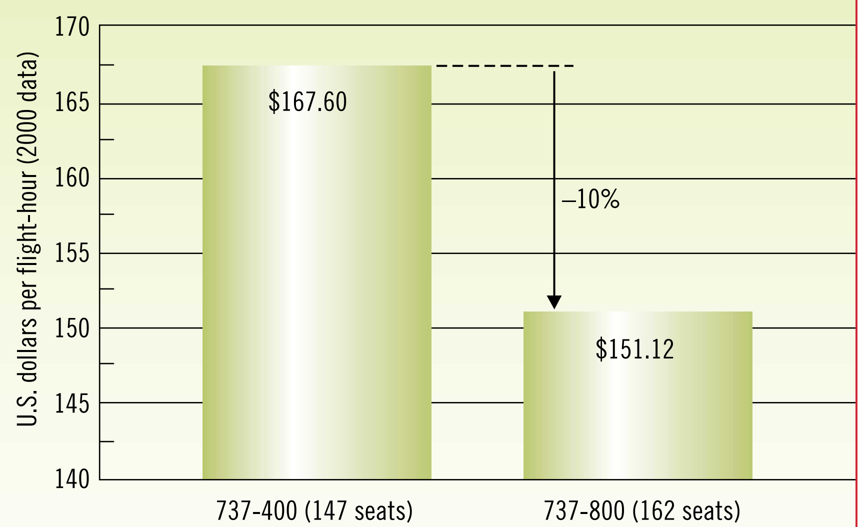
Training. The 737-600/-700/-800/-900 team also made improvements in maintenance training, in part to take full advantage of the enhanced service manuals. Mechanics are trained more efficiently using new maintenance-oriented courses and line-oriented simulator sessions. The training uses the same systems description section contained in the AMM. Classes are conducted through computer-based training, which is student paced, more frequently revised, and more interactive. Course materials were developed jointly with major suppliers and can be used for recurring training or as a refresher.

2 ACTUAL IN-SERVICE SAVINGS REALIZED BY AIRLINES

Early indications are that the 737-600/-700/-800/-900 family of airplanes is meeting the projected goal of a 15 percent reduction in airframe maintenance costs. With airlines moving into their second and third years of 737-600/-700/-800/-900 operation, actual cost data are becoming available. (First-year operators are excluded from maintenance cost analysis because an airplane's initial introductory period can skew results.)

FIGURE 4a AIRFRAME MAINTENANCE COSTS — U.S. DOT

Comparative total adjusted airframe maintenance costs for U.S. airlines operating 737-400s and 737-800s based on U.S. Department of Transportation (Form 41) data.



Note: Values shown are for labor and material, are based on a weighted fleet average, and are adjusted for a common flight time, airplane aging, and contract costs.

Boeing performed its analysis using actual airline maintenance costs. Where possible, airlines were selected that operated both the earlier 737 models and 737-600/-700/-800/-900s to normalize labor rates, line accounting practices, and operating efficiencies, and to give a true comparative picture of costs.

Looking at cost data reported to the U.S. Department of Transportation, 737-800 total airframe maintenance costs were nearly 10 percent lower than those of the comparable 737-400 model (fig. 4a). On a per-seat basis, the 737-800 maintenance costs were 18 percent lower than those of the 737-400 (fig. 4b). Assuming an annual airplane utilization of approximately 3,000 flight-hours, the cost saving equates to approximately US$50,000 per airplane per year.

Reviewing similar data reported to the International Air Transportation Association's Production Performance Measurement group (IATA/PPM), the maintenance costs for the 737-700 were nearly 14 percent lower than that of the comparable 737-300 (fig. 5). Because the 737-600/-700/-800/-900 airplanes were designed as a family, they share the same design principles and virtually identical systems. As such, this comparison analysis can be applied to all new 737 models.

A recent Maintenance Cost Protection Program (MCPP) review with a European operator supports the projected reduced costs. MCPP is a Boeing program offered to airlines to mitigate maintenance cost risk. The program provides for corrective action by Boeing if airframe maintenance costs exceed target levels. The specified target level was approximately 15 percent lower than established costs for the earlier 737 models operated by the airline. A detailed maintenance cost review by both Boeing and airline personnel was performed, which included the material consumption list, rotable and repairable parts, and warranty claims. The analysis revealed that actual airframe maintenance costs were 18 percent lower than the established MCPP target for the one-year period July 1998 to June 1999.

As airlines gain more experience with the new 737 models, reported costs are expected to be even lower than the predicted cost reductions. It is important to note that an airline's actual maintenance costs will vary depending on its specific scheduled maintenance plan, contract maintenance agreements, local labor rates, cost accounting practices, operating environment, and airplane utilization.

FIGURE 4b AIRFRAME MAINTENANCE COSTS, PER-SEAT BASIS — U.S. DOT

Comparative total adjusted airframe maintenance costs per seat for U.S. airlines operating 737-400s and 737-800s, based on U.S. Department of Transportation (Form 41) data.

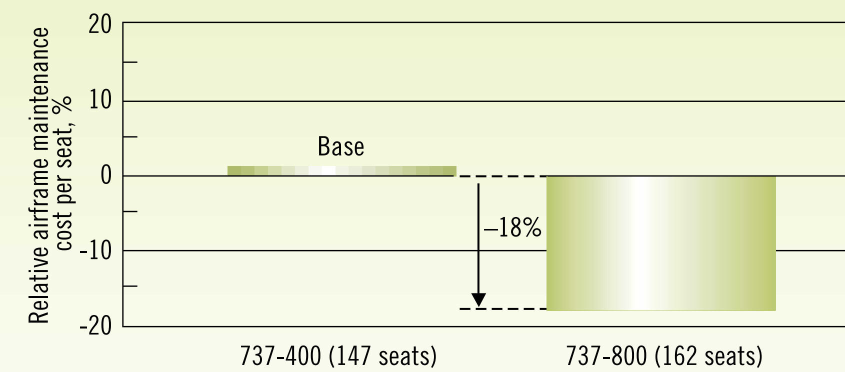
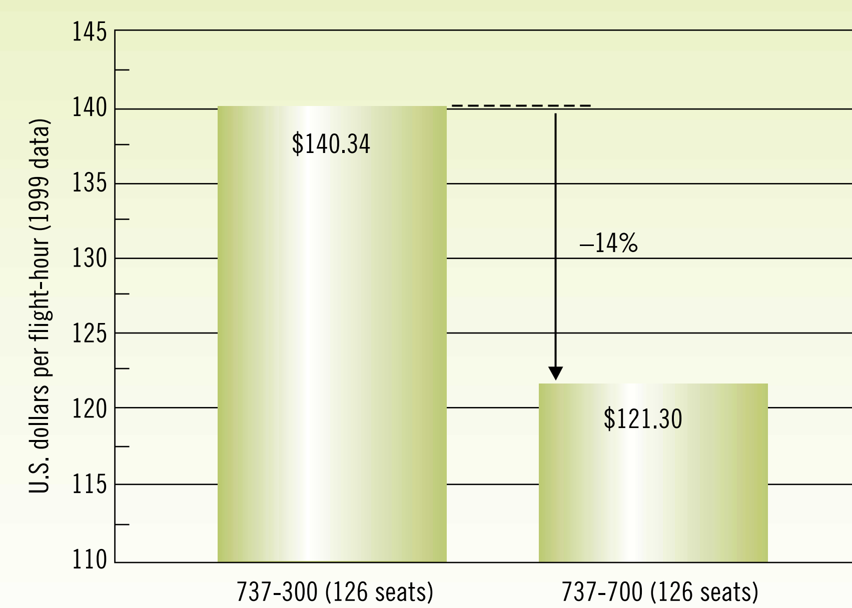


FIGURE 5 AIRFRAME MAINTENANCE COSTS — IATA/PPM

Comparative total adjusted airframe maintenance costs for an airline operating both 737-300s and 737-700s based on International Air Transportation Association Production Performance Measurement data.



Note: Values shown are for labor and material and are adjusted for a common flight time, airplane aging, and contract costs.

SUMMARY

Maintenance activities for the 737-600/-700/-800/-900 family of airplanes were reduced through improved airplane design, reduced scheduled maintenance, enhanced training, improved technical manuals, and improved access to technical data. Reduced maintenance activities translate directly into lower operating costs for the airlines.

The goal of the new airplane program was to reduce airframe maintenance costs by 15 percent, relative to the 737-300/-400/-500, which had set the standard for lowest operating costs in its class.

Although realized improvements in maintenance costs are a function of individual airlines' maintenance policies, operating parameters, and labor market, early indications are that the 737-600/-700/-800/-900 overall is well along toward meeting the projected cost-reduction goal.