Aircraft Maintenance -- Quality Cost to the Airline

Author

Mahmood Manzoor
Component Overhaul Shop
Engineering & Maintenance Department

Pakistan International Airlines Corporation
Quaid-e-Azam International Airport,
Karachi - Pakistan
E-mail: mmanzoor@piac.com.pk
AIRCRAFT MAINTENANCE – QUALITY COST TO THE AIRLINE

by

Mahmood Manzoor
Pakistan International Airlines Corporation
Karachi - Pakistan

During the past decade, quality has become a focal point of activity more than any other subject of interest to business managers the world over. Businesses have been motivated by fashion, campaigns, prizes and fear to go for quality. It is a fashion at the present time to focus on quality as a means of increasing competitiveness. National campaigns [like in Japan] have attempted to motivate the businesses to improve their quality. Prizes [Malcolm Baldrige National Quality Award, Shingo Prize] are awarded to businesses which achieve excellence in quality. Many businesses live in fear of losing business if they don’t achieve quality standards.

The aircraft industry is no exception to this paradigm. It is one of the most regulated industries in the world. Everything; the airspace, aircraft manufacturing, flight operations, aircraft maintenance, maintenance procedures and the rest, is regulated. Regulations ensure that the quality systems work. Voluntary or not, the adherence to these regulations have made the airline industry, both quality intensive and quality dependent.

But unfortunately, the measure of quality, the cost of quality, is still unclear amongst the business managers. To get to that topic however, there is a need to define quality first.

1. NEW THOUGHTS ON AN OLD CONCEPT

1.1. QUALITY DEFINED

Quality has many meanings; a degree of excellence, the totality of characteristics that has the ability to satisfy the stated and the implied needs of the customers, fitness for use, freedom from defects/imperfections and conformance with requirements. Any product or service that does not meet the customer requirements cannot be said to have quality. Therefore, a fundamental definition of quality is ‘conformance to requirements’.

1.2 COST OF QUALITY

It is now time to define the cost of quality, which has had different definitions and different understandings with the business managers; what is included in it, what is excluded from it, and how to calculate it.

In simple words, cost of quality is what it costs to do things wrong. Alternately, the cost of quality is the total of all costs incurred because failure is possible. The actual cost of production is the ‘no failure’ costs plus the ‘quality’ costs. The ‘no failure’ costs are the costs of doing the right things right first time. The ‘quality’ costs are costs of non
conformance to the requirements and include costs due to poor quality [failure costs; internal & external] and costs associated with improving quality [appraisal and prevention].

1.3 CALCULATING THE COST OF QUALITY

The understanding of the costs of quality is extremely important for establishing a quality management strategy. Calculating the costs of quality becomes important for a business for feeling the impact of these costs on the operations of the business.

The difficulties with the old classic approach of determining the costs of quality are many:

- It is after the fact when the damage has already been done and is difficult to segregate the ‘no failure’ costs and the quality costs.
- It is very costly to spend resources discovering errors and correcting them.
- There is absolutely no guarantee that all the errors can be identified.

If quality is conformance to the requirements then the only valid measure of cost of quality is the Price of Nonconformance (PONC). In other words, how much does it cost to discover and correct the errors? But question arises as how to calculate the PONC in thousands of activities which comprise all the aircraft maintenance works of an airline?

The answer probably lies in the concept of ‘Activity Based Costing’ or ABC as it is more commonly known. ABC allocates costs to specific activities rather than the departments or functions and these include labor costs, material costs, overheads, etc. The activities may be divided into three main categories:

- Productive activities: These are the budgeted operating costs.
- Corrective activities: Inspection after the fact and then correcting the nonconformance (defects).
- Preventive activities: Ensuring that the processes and procedures will lead to the desired results (conformance to requirements) every time the first time.

The first category is the normal operating activities in the airline and this includes all the direct operating costs. The only reduction which can be brought to this category, without impairing the operations, is through efficiencies from innovative processes.

The corrective activities, the undesirable work of discovering and correcting errors, is what every airline is trying to minimize, or altogether eliminate. But, in spite of the best efforts, this cost represents on the average about 35% of the operating budget in an airline.

The prevention category is designed to help do the productive activities correctly. In the strict sense of the word this is not a productive activity, but if neglected it could damage the productive ones. Therefore, this activity is desirable as well as a budgeted one. Eventually an airline will want reductions in the expenditures in this category also.

As can be seen, ABC helps in focusing attention on the category that needs more attention and since the accounting books under ABC will reflect costs allocated by activities, it makes finding and reporting the cost of quality an easy exercise. What ABC tells is which activity absorbs which of the costs.
2. EVOLUTION OF AIRCRAFT MAINTENANCE

Since the 1930’s, the evolution of aircraft maintenance can be traced through three distinct generations:

2.1 THE FIRST GENERATION

The first generation covers the period up to the World War II. In those days the aircraft industry was not very highly mechanized. This meant that the prevention of failures of aircraft systems/aircraft components was a low priority. At the same time, most aircraft systems/aircraft components were simple and generally over designed. As a result, there was no need for systematic maintenance of any sort beyond simple servicing. The repairs were done as and when required.

2.2 THE SECOND GENERATION

Things changed dramatically during World War II. By the 1950’s aircraft were more numerous and more complex. Industry was beginning to depend on them. As this dependence grew, Aircraft on Ground (AOG) times due failures came into sharper focus. This led to the idea that failures of aircraft systems/aircraft components could be and should be prevented, which led in turn to the concept of preventive maintenance. In the 1960’s, this consisted mainly of overhauls of aircraft systems/aircraft components done at fixed intervals.

The cost of maintenance also started to rise sharply relative to other operating costs. This led to the growth of maintenance planning and control systems. These have helped greatly to bring maintenance under control, and are now an established part of the practice of maintenance.

Finally, the amount of capital tied up in aircraft together with a sharp increase in the cost of that capital led airlines to start seeking ways in which they could maximize the life of the aircraft systems/aircraft components.

2.3 THE THIRD GENERATION

Since the mid-seventies, the process of change in the aircraft industry gathered even greater momentum. These changes can be classified under the headings of new expectations from aircraft maintenance, new research and new techniques in the aircraft maintenance practices.

2.4 NEW EXPECTATIONS

The figure 1 in the following paragraph show how expectations of aircraft maintenance have evolved. ‘Aircraft on Ground’ (AOG) times [due failures] have always affected the aircraft operations by reducing the aircraft availability, increasing operating costs and interfering with flight schedules. By the 1960’s and 1970’s, this became a major concern to the airlines. The effects of AOG have been aggravated by the world wide move towards ‘just in time’ inventory management. The stock levels in general have been reduced to the point that minor failures of aircraft systems/aircraft components can now have a major impact on aircraft operations.
In recent times, the growth of automation in the aircraft industry has meant that reliability [and hence the aircraft availability] has also become key issue. Greater automation also means that more and more failures affect the ability to sustain satisfactory quality standards. This applies as much to standards of service as it does to product quality.

The maintenance of aircraft facilitates the identification of causes of the failures and develops procedures to prevent these failures. Skilled personnel, proper methodologies and tools, and refined technologies are now used to identify, predict and prevent failures.

At the same time as the dependence on aircraft is growing, so too is the costs to operate and to own them. To secure the maximum return on the investment that they represent, they must be kept in an airworthy condition and performing with efficiency.

Finally, the aircraft maintenance costs themselves are still rising, in absolute terms and as a proportion of total costs. In some airlines, it is now the second highest or even the highest element of operating costs. As a result, in only thirty years these have moved from almost nowhere to the top of the league as a cost control priority.

---

**The Three Generations**

**First Generation:**
- Repair when the failure occurs.

**Second Generation:**
- Higher aircraft availability.
- Longer life of aircraft systems/aircraft components.
- Lower costs

**Third Generation:**
- Higher aircraft availability and reliability.
- Higher safety.
- Better maintenance quality.
- Environment consciousness.
- Longer life of aircraft systems/aircraft components.
- Higher costs.

---

*Figure 1 Growing expectations of maintenance*
2.5 NEW RESEARCH

Quite apart from greater expectations, new research is changing many of our most basic beliefs about age and failure. In particular, it is apparent that there is less and less connection between the operating age of most aircraft systems/aircraft components and how likely they are to fail. The earliest view of failure was that as things got older, they were more likely to fail. A growing awareness of ‘infant mortality’ led to widespread second generation belief in the ‘bathtub’ curve mode of the failures.

However, Third Generation research has revealed that six failure patterns actually occur in practice. One of the most important conclusions to emerge from this research is a growing realization that although they may be done exactly as planned, a great many traditionally derived maintenance programs achieve nothing, and some are even actively counterproductive. This is especially true of many programs done in the name of preventive maintenance. On the other hand, many more maintenance programs that are essential to the safe operation of modern aircraft do not appear in the associated maintenance programs. In other words, airline industry in general is devoting a great deal of attention to doing maintenance work correctly (doing the jobs right), but much more needs to be done to ensure that jobs which are being planned are the jobs that should be planned (doing the right jobs).

2.6 NEW TECHNIQUES

There have been explosive growths in new maintenance concepts and techniques. Many have been developed over the past years, and more are emerging. The new developments include:

- decision support tools, such as hazard studies, failure modes and effects analyses and expert systems
- new maintenance techniques, such as condition monitoring
- designing equipment with a much greater emphasis on reliability and maintainability
- a major shift in organizational thinking towards participation, team-working and flexibility.

As mentioned earlier, a major challenge facing the aircraft maintenance nowadays is not only to learn what these techniques are, but to decide which are worthwhile and which are not, in their own airlines. If the right choices are made, it is possible to improve performance of aircraft systems/aircraft components and at the same time contain and even reduce the cost of maintenance. If the wrong choices are made, new problems are created while existing problems only get worse.

2.7 THE CHALLENGES FACING MAINTENANCE

The commercial aviation industry was the first industry to confront these challenges systematically. A crucial element of its response was the realization that as much effort needs to be devoted to doing the right jobs as to ensuring that the jobs are done right. This realization led in turn to the development of the comprehensive decision-making process known within aviation as MSG3.
3. AIRCRAFT MAINTENANCE COST CONCEPTS

The objective of aircraft maintenance is to provide flight safety and reliability at the minimum cost. The increase in the AOG time [due to failures] limits the aircraft availability and the operational efficiency. To improve the aircraft availability, it is necessary to maintain the reliability at the desired levels. For this reason, the maintenance actions which can improve safety and dispatch reliability of the aircraft, while reducing costs at the same time, will always affect the success of maintenance organizations. Aircraft maintenance costs have now become of prime concern to the airlines.

3.1 AIRCRAFT MAINTENANCE: MANAGEMENT OF FAILURES

The scope of aircraft maintenance is defined by the functions and the performance expectations of the aircraft systems/aircraft components. The only possibility to stop an aircraft system/aircraft component performing to the required expectation is its failure. This failure can either be a total failure (inability to function to an acceptable performance expectation) or a partial failure (function to an unacceptable performance expectation). This suggests that aircraft maintenance is an approach to the management of failures of aircraft systems/aircraft components. The aircraft maintenance schedule is thus based on procedures which contribute towards the management of failures of the aircraft systems/aircraft components and can be done by adopting two strategies:

- Managing the consequences of failures.
- Managing the occurrences of failures.

The first step in the management of failures of the aircraft systems/aircraft components is to identify the causes of these failures. These may include:

- Those causes that resulted in the failure of the same or similar equipment operating under the same conditions.
- Those causes that are currently being prevented by existing maintenance procedures.
- Those causes that may happen to be a possibility during the aircraft operation.

Most traditional lists of these causes include deterioration or normal wear and tear. However, the list should also include causes due to human errors and the design discrepancies, so that all possible causes of failures of aircraft systems/aircraft components can be identified and an appropriate policy for the management of these failures may be applied.

3.2: MANAGING CONSEQUENCES OF FAILURES: BASICS

The failures of aircraft systems/aircraft components during the normal operations affect any airline in some way or the other. These failures may affect the airline’s flight schedules. These may also affect quality, reliability and safety of the aircraft systems/aircraft components. Most important, these all cost the airline significant time and money to have these failures repaired.
It is these consequences that decide the extent of maintenance required to manage the failure of aircraft systems/aircraft components. If a failure has serious consequences, extensive maintenance will be required and if it has little or no effect, a routine maintenance to the extent of normal servicing should suffice. Aircraft maintenance procedures recognize that the consequences of failures are far more important than their technical characteristics, and focus on reducing the consequences of these failures.

The maintenance actions which can be taken to deal with these failures, and are chosen when it is not possible to identify an effective proactive action, include:

- **Trouble-shooting**: It involves determining the reasons of the failure of the aircraft system/aircraft component.
- **Repairs**: It entails restoration of the failed aircraft system/aircraft component to the serviceable condition.
- **Modification**: It necessitates making any one-time change to the capability of an aircraft system/aircraft component.

### 3.3 AIRCRAFT MAINTENANCE: MANAGING CONSEQUENCES OF FAILURES

The management of consequences of failures is limited to minimizing the impact of these failures. It is a reactive approach, but nevertheless necessary. Ideally speaking, the airlines should encounter no situation that necessitates applying this strategy. But the airline operation is far from being an ideal scenario. Failures occur and will keep on occurring; the airline can only strive to minimize the impact of these failures.

- **Fault Isolation Manuals (FIMs)** are used for the troubleshooting of the failures so that the aircraft is restored to an airworthy condition in minimum possible time.
- **The Minimum Equipment List (MEL)** is intended to permit operations with inoperative aircraft system/aircraft component for a period of time until repairs can be accomplished. Repairs are to be accomplished at the earliest opportunity and not later than the ‘Repair Interval Category’ stated in the MEL. Here also, the intent is on minimizing the impact of failure.
- **Flight Packs** are carried on board the aircraft and have aircraft components which are more prone to failures and which may be required to be replaced more often than other aircraft components. At outstations the aircraft is restored back to airworthy condition by replacing defective components from the flight pack.
- **International Airlines Technical Pool (IATP)** is an airline organization. Under the auspices of the IATP, members share aircraft parts, aircraft tooling, ground handling equipment, and manpower. The IATP reduces airline operational delays, cancellations, and costs by sharing resources.

### 3.4 CONSEQUENCES OF FAILURES: QUALITY COSTS

The traditional internal failure costs for any business include scrap, rework, retest, down time, material review board, and corrective actions before the delivery to the external customer while external failure costs include all costs incurred to rework or repair the product/service after the delivery to the external customer. This includes returns, warranty expenses, returned material handling, complaint handling etc.

In the case of an airline the ‘external’ customer for any airline’s maintenance department is the flight operations [aircraft crew]. Therefore the internal failure costs for aircraft
maintenance will include all costs incurred to repair the failures of aircraft systems/aircraft components before the aircraft is released out of maintenance and accepted by the aircraft crew. The external failure costs hence will include all costs resulting out of any failures during aircraft operation after it has been released out of maintenance.

The list of these costs can be extensive and can have very serious impacts on the airline operation, and following is a list to name a few:

- Flight delays.
- Flight cancellations.
- Flight diversions.
- Compensation and hotel accommodations for passengers.
- Disruption of airline’s flight schedule.
- Aircraft on ground (AOG) time increase.
- Non-availability of aircraft limiting operational efficiency.
- Reduced utilization of aircraft.
- Increased aircraft turn around time between the flights.
- Increased passenger complaints/Lost passengers.

### 3.5 MANAGING PREVENTION OF FAILURES: EVOLUTION

When the consequences of failures of aircraft systems/aircraft components are significant, emphasis is shifted on preventing the occurrences of the failures instead of managing the consequences of the failures. Maintenance actions are required to prevent or predict the failures. This brings in the subject of proactive (preventive) approach to the management of failures.

Second Generation wisdom suggested overhauls or component replacements at fixed intervals regardless of its condition at the time based on the assumption that most aircraft systems/aircraft components operate reliably for a specified period, and then wear out. It also suggested that sufficient records of failures can enable determination of this period so as to take preventive action shortly before the aircraft systems/aircraft components is due to fail. This was only true where age-related factors were present in the design of the aircraft components.

![Figure 2: The traditional view of failure](image)

With aircraft systems/aircraft components becoming more complex significant changes in patterns of failure started emerging, as shown in Figure 3. The graphs show probability of failures against operating age.
Figure 3: Six new emerging patterns of failure

- Pattern A is the well-known bath-tub curve. It begins with high incidence of failure (infant mortality) followed by constant or gradually increasing probability of failure, then by a wear-out zone.
- Pattern B shows constant or slowly increasing probability of failure, ending in a wear-out zone.
- Pattern C shows slowly increasing probability of failure, but there is no identifiable wear-out age.
- Pattern D shows low probability of failure when the item is new or newly overhauled, then a rapid increase to a constant level.
- Pattern E shows a constant probability of failure at all ages (random failure).
- Pattern F starts with high infant mortality, then constant or slowly decreasing probability of failure.

These findings contradict the belief that there is always a connection between reliability (and failures) and operating age, in fact scheduled overhauls often increase failures by introducing infant mortality into a stable aircraft system/aircraft component.

The continuing need to prevent failures, and the growing inability of classical techniques to do so, are factors behind the growth of new techniques of failure management. These techniques rely on the fact that most failures give some warnings of the fact that they are about to occur and these warnings can be used to detect potential failures. Hence actions can be taken to reduce or eliminate the consequences which could occur if they were to deteriorate into functional failures. The management of prevention of failures thus focuses on the maintenance activities that have most effect on the performance of the airline, and diverts energy away from those that have little or no effect. Failure management techniques are undertaken before failure occurs, in order to prevent the aircraft system/aircraft component from getting into a failed state.

Whether or not a proactive action is technically feasible is governed by the technical characteristics of the action and of the failure that it is meant to prevent. Whether it is worth doing is governed by how well it deals with the consequences of the failure. However, a proactive action is only worth doing if the total cost of doing it over a period of time is less than the cost of the operational consequences and the cost of repair over the same period. In other words, the task must also be justified on economic grounds.
3.6: AIRCRAFT MAINTENANCE: PREVENTION OF FAILURES

With the introduction of jet aircraft, the aircraft maintenance philosophies started changing and resulted in the evolution of maintenance process known as ‘Condition Monitoring’. It started from the theory of preventive replacement or restoration, known as ‘Hard Time’ within the airline industry, whereby aircraft systems/aircraft components were overhauled at set frequencies. However, it was eventually demonstrated that there was no correlation between the frequency of ‘Hard Time’ preventative maintenance and the reliability [and the failures] of the aircraft systems/aircraft components.

Simultaneously, significant improvements in reliability of aircraft systems/aircraft components took place with the improvements in manufacturing techniques, introduction of new technologies, and developments in avionics in control and display systems.

These developments prompted the airlines to seek a more consistent set of rules through which maintenance programs could be determined for changes in the ‘Hard Time’ philosophy. Hence new radically different maintenance philosophy evolved with the concepts of ‘On Condition’ and ‘Condition Monitored’ components. This involved watching the deterioration of a component as it trends towards a failure, the analysis of pre-selected operating characteristics of an aircraft system/aircraft component and its comparison against a known standard.

Aircraft components could remain ‘On Condition’ if suitable inspections could be accomplished on the aircraft to determine the continued serviceability of these components until the next scheduled inspection. Hence the ‘On Condition’ components are subject to regular checks so that, as far as possible, these can be replaced or removed before they are likely to fail. The condition monitored components include non safety components (passenger reading lights etc.) which are to be replaced on failure.

The results from the ‘Condition Monitoring’ maintenance process alert the maintenance staff to impending failure of an aircraft system/aircraft component. Hence repair or replacement action can be scheduled before a failure occurs.

3.7 AIRCRAFT MAINTENANCE: QUALITY SYSTEM CERTIFICATION

Another step forward to this approach is the establishment of a quality system within the airline. A quality system certification [FAA OR JAR-145] takes the airline towards a total quality management environment. Such a system enables an airline to achieve, sustain and improve quality economically. Quality costs are effectively taken care of by the establishment of a quality system within the airline. However, it is beyond the scope of this paper to address this subject in details.

4. AIRCRAFT MAINTENANCE AT PIA

The two basic characteristics of the airline industry are the high operating costs and low profit margins. Today the airlines’ revenues are decreasing while the operating costs are increasing. The need for controlling the airlines’ cost is greater today than ever.

Aircraft maintenance costs are the major contributors in the direct operating costs (DOCs) of the airlines and are unique items in their DOCs because these can potentially be controlled by the airlines. Therefore reducing the aircraft maintenance costs is very important for airlines to increase their profit margins.
Pakistan International Airlines (PIA) is no exception to this scenario. The aircraft maintenance costs reflect a sizable amount in PIA’s income-statement, making it more important for the airline to strive for reducing these costs. PIA’s Engineering & Maintenance Department is an excellent example of a facility where there is a great focus on controlling and reducing the aircraft maintenance costs without compromising on aircraft safety and reliability. The latest concepts of condition monitoring preventive maintenance programs are applied for the aircraft maintenance and significant cost savings are achieved.

4.1 MANAGING CONSEQUENCES OF FAILURES AT PIA

Like any other airline, failures of aircraft systems/aircraft components occur within PIA also. The first step taken by the PIA’s Engineering & Maintenance Department under these circumstances is to minimize the consequences of these failures. Failures at Base are repaired as per the contents of FIMs in the shortest possible time to avoid any aircraft delay or disruption of flight schedule. Failures at outstations are handled in the light of MEL allowances and if required the aircraft Flight Pack is used to replace any defective aircraft component. The facility of IATP is utilized when aircraft components are required to be replaced which are not part of the Flight Pack. The strategy underlying all these maintenance actions is to minimize the consequences of such failures [aircraft delays].

4.2 ANALYSES OF FAILURES AT PIA

The story of management of consequences of failures does not end with the restoration of the aircraft to an airworthy and serviceable condition. There is much more to it. The failure of an aircraft system/aircraft component, though not a welcome occasion for the PIA’s Engineering & Maintenance Department, yet it is viewed as an opportunity for improvement and a source of learning and enrichment of experience so that future failures can be avoided.

The analysis of every failure goes into the ‘reliability data base’ of the PIA’s Engineering & Maintenance Department. Calculations are done to arrive at the MTBRs, MTBFs and removal rates for each aircraft component. The removal rate of an aircraft component is \[
\frac{1000 \times \text{number of component removals per month}}{\text{Aircraft flight hours} \times \text{number of component per aircraft}}
\]. The mean of aircraft component removal rates over a thirty (30) months period is considered to be its ‘Good Performance Level (GPL)’. Two standard deviations of removal rates are added to the GPL to arrive the alert level for that particular aircraft component.

The component reliability is determined on the basis of alert levels and GPLs established from the sample data of components removed over a thirty (30) months period. Alert level status is used to indicate the improving or deteriorating performance of any aircraft component.

The alert levels and GPLs are frozen and don’t change as the data of new month is added. However these values are calculated on the basis of removals during the last thirty (30) months period, which may be adopted as a new standard on the discretion of MRB.

If the removal rate in the current month is below the GPL, the alert status is green, and if it exceeds the GPL, the alert status becomes amber. The alert status becomes red if
the removal rate has exceeded the GPL not only in the current month but also in the last six months.

4.2: PREVENTIVE AIRCRAFT MAINTENANCE PROGRAMS AT PIA

Where does all this exercise lead to? Certainly it is not for the sole purpose of accumulating data. Based upon the MTBRs, MTBFs, removal rates and the analyses, necessary checks and maintenance actions are introduced (if required) for the aircraft component so as to minimize the possibility of failure of the aircraft component in future which is the essence of condition monitoring preventive maintenance programs.

It will be beyond the scope of this paper to describe the details of all the activities of PIA’s Engineering & Maintenance Department in this context. But one example will enable the readers to visualize how well the concepts of condition monitoring preventive maintenance programs are being applied and how significant reductions in aircraft maintenance costs are being achieved.

4.3 COST REDUCTION PRACTICES AT PIA: AN EXAMPLE

Taking guidance from Activity Based Costing (ABC) concept, quality costs of individual components are calculated for review. The component selected for the paper is the Airbus A300 Slat Screw Jack, whose failures during the period 1997-1999 resulted in significant costs to the airline. The analysis of the failures confirmed that excessive backlash between the nut and the screw of the Ball Screw Assembly of Slat Screw Jack was causing the failures. PIA does not have in-house repair capability for this Ball Screw Assembly; hence it has to be sent abroad for repairs. The cost of repairs is high and in foreign exchange, which made paying attention to its failures more important.

The A300 Slat Screw Jack is an ‘On Condition’ component with an on wing maintenance check at 3750 flight hours to determine its condition. Experience at PIA showed that this check could not predict the impending failures satisfactorily. Based on the analysis of the failures, it was decided that instead of checking the back lash between the nut and screw on wing, the unit should be removed from the aircraft and sent to the Overhaul Shop where the check could be done more accurately. Initially it sounded like adding more costs to the maintenance, but in the longer run this exercise resulted in reduction in failures. The units removed from the aircraft were checked in the Overhaul Shop in details, necessary servicing was done and the units were made serviceable for another operational life on the aircraft. The ultimate failures of the units were thus avoided and requirements to send these units abroad for repairs were eliminated.

The A300 Slat Screw Jacks are now removed from the aircraft before the failure occurs, serviced in Overhaul Shop and put back on aircraft for service till the next check. The appraisal and preventive quality costs are added but the failure costs are saved. The savings are on two accounts:

- Numbers of failures were decreased by about 40 percent.
- Repair costs were decreased by about 70 percent.

The overall impact was that savings of about 90 percent were achieved only in this activity. The figures in the following paragraph show the same results in dollar values.
This one example illustrates how well the philosophies of modern aircraft preventative maintenance programs are being applied at PIA’s Engineering & Maintenance department. Examples like the one cited exist in numbers and efforts continue on regular basis in this direction. The impacts of quality costs on aircraft operation are well understood at all the management levels of PIA’s Engineering & Maintenance department, and all possible actions are taken to minimize these impacts. The first focus is on reducing the failure costs by investing in appraisal and preventive costs, and as the next step, achieving reductions in the appraisal and preventive costs, without impairing the airworthiness of aircraft, also remains a priority.

### 4.4 COST REDUCTIONS: A BROADER PICTURE

The savings achieved in quality costs by the aircraft preventive maintenance programs in the dollar values illustrate one of tangible benefits out of these programs, but these benefits extend beyond this factor. Many other tangible and intangible benefits occur by following these aircraft preventive maintenance programs and the list highlight few of these:

- Improvements in reliability and thus greater availability of aircraft occurs which reduces the number, length and cost of flight delays.
- Reductions in the number and length of flight delays ensure that the flight scheduled are met and flight cancellations are prevented.
- Dispatch reliability and utilization of aircraft are improved.
- Aircraft turn around time is decreased.
- Reduced failures allow more time to other scheduled maintenance jobs, which results in better quality of maintenance job.

<table>
<thead>
<tr>
<th>Year</th>
<th>Failures</th>
<th>Quality Cost US$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1997</td>
<td>45 units</td>
<td>405,000</td>
</tr>
<tr>
<td>1998</td>
<td>45 units</td>
<td>405,000</td>
</tr>
<tr>
<td>1999</td>
<td>54 units</td>
<td>486,000</td>
</tr>
<tr>
<td>3 Years</td>
<td>144 units</td>
<td>1,296,000</td>
</tr>
<tr>
<td>Per Year</td>
<td>48 units</td>
<td>432,000</td>
</tr>
<tr>
<td>2000</td>
<td>27 units</td>
<td>54,000</td>
</tr>
<tr>
<td>2001</td>
<td>29 units</td>
<td>58,000</td>
</tr>
<tr>
<td>2 Years</td>
<td>56 units</td>
<td>112,000</td>
</tr>
<tr>
<td>Per Year</td>
<td>28 units</td>
<td>56,000</td>
</tr>
</tbody>
</table>

**Figure 4: Status of cost savings**
Reduced failures also allow lower inventory levels of spare float of aircraft components, thus reducing the investment costs in this category.

Reduced failures also allow a reduced level of inventory of consumable materials and spares, lowering the costs for purchasing and maintaining this inventory.

5. CONCLUSION

The understanding of the costs of quality is extremely important in establishing an aircraft failure management program. After discussing the three major costs of quality and their applications, it is evident how these affect an airline. The more an airline invests in appraisal and preventive measures, the more it will be able to reduce the failure costs. The appraisal and preventive costs have a direct relationship with quality conformance. The quality conformance has an inverse relationship with failure costs. Understanding these relationships and applying costs of quality process enables an airline to decrease failure costs.

The airline industry has undergone a prominent change during the last decade:

- Aircraft have become more sophisticated and increasingly complex.
- Passengers have become more demanding and their expectations from the airlines have become more idealistic.
- Labor costs, maintenance costs and spares costs have increased.
- Competition amongst the airlines has become more fierce.

All these developments call for a pro-active approach rather than a reactive approach by the airlines towards the aircraft maintenance. More emphasis, therefore, will have to be placed on reducing the costs of aircraft maintenance and efforts will be required to improve the quality systems of the airlines to achieve these cost reductions.

AUTHOR’S SYNOPSIS

Mahmood Manzoor has over Thirty (30) years of aviation experience with Pakistan International Airlines Corporation. He is a Mechanical Engineering from NED University of Engineering & Technology, Karachi. He did his Master of Business Administration from Institute of Business Administration, Karachi. Mr. Mahmood Manzoor is a Certified Quality Professional from NED University of Engineering & Technology / Pakistan Institute of Quality Control and a Certified Quality Manager for American Society for Quality (ASQ). He has also possessed the Lead Auditor Course Certificate from Moody International, England.
APPENDIX A:

REFERENCES:


• ‘Applying MSG-3 to out of Production Aircraft’. Aircraft Technology Engineering & Maintenance: February-March 2001

• ‘Costing Organizational Activities’. Handbook of Standards & Guidelines: November 30, 1995